NEW YORK FISH AND GAME JOURNAL

VOLUME 18 July, 1971 NUMBER 2

COMPARISON OF FIELD METHODS FOR MEASURING STREAM DISCHARGE[1]

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ABSTRACT

Stream discharges were measured by a modification of Embody's float method and by two salt-dilution methods using a specific conductivity meter. In one of the latter, salt solution was introduced from a plastic constant-flow carboy. In the other, salt was introduced by solution from pre-weighed salt blocks. A precise relationship between sodium chloride concentration, temperature and specific conductivity is given in nomographic form, permitting rapid determination of changes in salt concentration. Comparison with USGS stream-gage readings showed that each method, when used in a suitable location, provided discharge measurements sufficiently accurate for most aquatic biological applications. The salt-dilution methods, in particular, can be used in very shallow, very turbulent and very sluggish streams where the more standard current-meter method is not applicable. Between them, the three methods described provide means for fairly rapid, easy and inexpensive gaging of the great majority of small and medium-sized streams.

Fisheries biologists frequently need to determine the discharge of a stream in cubic feet per second. The precision and accuracy required of such measurements depends upon their purpose. If, as was usual in the past, stream discharge is measured merely as a part of the description of a lotic environment, to be used as a guide for fish management or as background information for environmental study, a rough measurement is usually sufficient. If, however, a chemical is to be metered into a stream at a constant rate to obtain a particular concentration, or if the stream is to be sampled quantitatively for fish eggs, fry or invertebrate drift, more precision is needed. Recent increases in chemical treatment of streams and quantitative drift sampling call for a re-evaluation of some of the approximate gaging methods used in the past and for development of new methods that are simple, accurate and adaptable to a wide range of stream conditions.

[1] The author wishes to thank Roy E. Campbell, supervisory hydraulic engineer of the U.S. Geological Survey at the Middletown (N.Y.) sub-district office, and Kenneth I. Darmer, chief of the hydrologic studies section of the U.S. Geological Survey at the Albany (N.Y.) office, for providing access to gaging stations, stream rating tables and hydrological literature as well as for several helpful discussions. He wishes to thank Howard A. Loeb who worked with him in field-testing the methods, offered a number of helpful suggestions and critically read the manuscript.

There are three basic approaches to the measurement of stream discharge:

1. The velocity × area approach. Stream velocity in feet (or meters) per second is multiplied by cross-sectional area in square feet (or square meters) to give discharge in cubic feet (or cubic meters) per second. This approach is used in the current-meter method employed by the United States Geological Survey for calibrating its gaging stations and in the float method described by Embody (1927) which is commonly used in fisheries work for approximate gaging under field conditions. Hydraulic engineers also use variations of this approach in which mean velocity at a point in a stream channel is estimated from depth, gradient, bottom roughness and other channel parameters. Such methods are approximate, mathematically complex and used mainly to estimate peak discharges during floods.
2. The tracer-dilution approach. A foreign substance susceptible of quantitative detection is introduced into the stream in such a manner that it mixes uniformly with the stream water. The water is sampled at a downstream station, the concentration of the tracer solution is measured, and discharge is computed by determining the volume of water needed to cause the measured amount of dilution. European hydrologists have long used salt-dilution techniques to gage turbulent mountain streams (Rouse, 1932; Østrem, 1964). The United States Geological Survey has experimented with dye dilution (Cobb and Bailey, 1965).
3. The stage-discharge curve approach. Certain structures may be placed in a stream channel that will create a strict mathematical relationship between the discharge passing through or over the structure and the vertical height of the water level above a given datum point. Examples are the Parshall flume and the V-notch, Cippoletti and rectangular weirs. Alternatively, a stage-discharge relationship may be determined empirically for a stable portion of a natural stream channel, as is done at USGS gaging stations. Since this approach requires permanent or semipermanent installations, it is not ordinarily used as a field method by fisheries personnel, except to take advantage of existing installations. If a stream has a USGS gaging station or a properly constructed gaging weir at the desired gaging point, field measurement of discharge is unnecessary.

In considering the details of any gaging method, one must keep in mind certain facts about streams. The distribution of velocities in a stream is never uniform. Not only are there obvious differences between pool and riffle areas, but there is a definite distribution of velocities within any stream cross-section. Velocity is a function of stream

gradient, viscosity and the frictional drag between the stream and the streambed. In a typical cross-section, surface velocity is greatest in the deep midchannel portion and least in shallow areas near the banks. At any unobstructed point in the cross-section, velocity is greatest at the surface, decreases gradually with increasing depth and finally decreases abruptly near the bottom. Study of a large number of vertical velocity curves (Buchanan and Somer, 1965) has shown that the mean velocity at a given location can be approximated by measuring the velocity at 0.6 of the total depth or by averaging the velocities at 0.2 and 0.8 of the total depth.

Whenever a soluble chemical is metered into a stream, turbulence, gravity and molecular diffusion cause it to spread out across the stream at a rate dependent on a whole complex of stream conditions. Bank-to-bank uniformity is often achieved quickly in narrow or turbulent streams. The leading edge of the chemical moves downstream with the swiftest water. If the chemical is sampled at a downstream point, concentration builds up and reaches a plateau when the water upstream has reached a stable distribution of concentrations. This occurs quickly in riffles and slowly in pools. Concentration builds up most slowly in eddies near banks or below rocks. These same eddies continue to feed the chemical back into the main current after chemical inflow has ceased and the main bolt of chemical has passed. A bolt of chemical solution moving downstream has a uniform, relatively concentrated plateau portion with leading and trailing edges. As it progresses downstream, dilution occurs at the upstream and downstream ends until the plateau disappears. Some slow dilution from small side eddies, seepage and stretch-out normally occurs within the plateau region.

During 1968, three successful and reasonably accurate methods for measuring discharge under field conditions were developed and tested at the Fish Laboratory at Livingston Manor (N.Y.). One is a modification and refinement of Embody's float method, which is in the velocity × area category. The other two are salt-dilution (i.e. tracer-dilution) methods employing a Beckman 2A-RA stream conductivity meter and a nomograph for converting specific conductivity to salt concentration in parts per million. In one of these, salt solution is metered into the stream at a constant rate from a light-weight plastic Mariotte bottle constructed by fitting a Nalgene aspirator carboy[2] with an air inlet tube extending almost to the bottom to provide a constant hydraulic head (Engstrom-Heg, 1971). With an adjustable fitting at the end of the inlet tube for varying the head, and a series of outlet apertures made by drilling holes in plastic screwcaps, a wide range of constant outflow rates can be obtained. In the other method, the salt is released into solution at a slowly decreasing rate from salt blocks placed in the

[2] Nalgene Labware Division, Nalge Company, Rochester, N.Y.

stream. All three methods were tested at several suitable sites located near USGS gaging facilities on Willowemoc Creek and the Little Beaverkill River. Estimates of discharge were compared with those obtained from USGS gage readings and rating tables.

These methods are described and discussed in comparison with related techniques.

VELOCITY × AREA METHODS

The current-meter method, as described in detail by Buchanan and Somers (1965) and by Pierce (1942), has long been the standard method employed by the United States Geological Survey. Briefly, it consists of determining the width, depth and estimated mean velocity of a series of 20 to 30 partial cross-sections as the worker progresses across the stream. Discharge is computed for each partial section, and the partial discharges are added to obtain the total discharge. Velocities are measured with a Price current meter mounted on a top-setting wading rod. Cable suspension is used in streams too large to wade. Properly used at a suitable location, the method is an excellent one. Extensive experiments by Carter and Anderson (1963) indicate that the standard deviation from the mean of a series of discharge measurements on a given stream at a given water stage is 2.2 per cent. Biologists working from stations equipped with calibrated Price current meters are well advised to use it on those streams where it can be used. However, it does have limitations. It does not give accurate readings in very shallow water (less than 7½ inches), or in rocky, turbulent, tumbling streams where the current includes strong diagonal and vertical components. In very sluggish streams, there is often insufficient current to operate the meter. Also, the equipment needed is moderately expensive where a wading rod can be used and quite expensive where cable suspension must be resorted to. Compared with the salt-dilution methods, gaging a stream with a current meter can be hard, tedious work, especially in very cold or hot weather.

The modification of Embody's float method was found to be quite satisfactory for use in medium-sized streams with moderate gradients. The technique used is as follows:

1. A 50-foot section having parallel banks and fairly uniform depths and velocities is marked off. Steel tapes are stretched across the stream at right angles to the current at the upstream and downstream ends of the section.
2. Depths are measured at both the upstream and downstream tapes at equal intervals across the stream. Analysis of several real and hypothetical stream channel cross-sections indicates that regardless of stream width, about 15 depth readings are needed to be sure of obtaining an accurate measurement of

cross-sectional area. A greater number will not significantly increase accuracy even when the bottom is quite irregular. Fewer measurements result in decreased accuracy, particularly where there are fewer than 10. Embody suggested using three depth measurements at each cross-section, but did not claim great accuracy for his method.

3. Floats, consisting of perforated plastic practice golf balls ("whiffle balls") painted a fluorescent red, are released and timed. One worker stands at the upstream tape with a bucket of floats and a recording pad. Another stands at the downstream tape with a stopwatch and a dip net. The upstream worker releases the floats at equal intervals from about 3 feet above the tape and calls out as the float passes the tape. The downstream worker catches the float as it passes the downstream tape, stops the watch and calls out the time of passage. Five equally spaced float passages are sufficient.
4. The areas of the upstream and downstream cross-sections are computed. Each depth measurement is taken to be characteristic of a partial cross-section. The width of any of the middle partial cross-sections is equal to the distance between depth measurements. The width of a partial cross-section adjacent to the bank is equal to the distance from the bank to a point halfway between the first and second depth measurements from the bank. The area of a partial cross-section is of course equal to its depth times its width. The sum of areas of partial cross-sections equals the total cross-sectional area. Where the widths of all partial cross-sections are equal, the cross-sectional area may be computed by multiplying the average depth by the total width. Even where there are shorter or longer partial cross-sections next to the bank, this procedure does not usually introduce any substantial error. The practice, recommended by Welch (1948), of determining the mean depth by dividing the sum of the depth measurements by one less than the number of measurements was found to result in overestimates of cross-sectional area ranging from 3 to 15 per cent. If depth measurements are averaged, a simple arithmetic mean should be used. The mean of the two cross-sectional areas is then computed.
5. An estimate of mean surface velocity is computed. Velocities for each float passage are determined by dividing distance by time. A mean is computed by dividing the sum of these velocities by the number of determinations. Determinations from marginal areas having velocities less than half the midstream maximum are not used. An estimate of mean velocity may be obtained by multiplying the mean surface velocity by an empirically determined constant, 0.75.

6. The estimated mean velocity is multiplied by the mean of the upper and lower cross-sectional areas to obtain an estimate of discharge.

An example, using hypothetical data, illustrates the procedure. Measurements for the two cross-sectional areas are given in Table 1. The average of these areas, 23.6 square feet, is the mean cross-sectional area of the stream.

TABLE 1. HYPOTHETICAL MEASUREMENTS FOR CROSS-SECTIONAL AREAS OF A STREAM

Upper cross-section				Lower cross-section			
Distance*§	Depth §	Width §	Area †	Distance*§	Depth §	Width §	Area †
0.5	0 (bank)	xxx	xxx	1.2	0 (bank)	xxx	xxx
2	0.3	2.5	0.7	2	0.2	1.8	0.4
4	0.4	2.0	0.8	4	0.1	2.0	0.2
6	0.3	2.0	0.6	6	0.5	2.0	1.0
8	0.6	2.0	1.2	8	0.7	2.0	1.4
10	0.9	2.0	1.8	10	1.3	2.0	2.6
12	1.0	2.0	2.0	12	1.3	2.0	2.6
14	1.2	2.0	2.4	14	1.5	2.0	3.0
16	1.2	2.0	2.4	16	1.2	2.0	2.4
18	1.4	2.0	2.8	18	1.1	2.0	1.6
20	0.9	2.0	1.8	20	1.0	2.0	2.0
22	0.8	2.0	1.6	22	0.8	2.0	1.6
24	0.6	2.0	1.2	24	0.8	2.0	1.6
26	0.4	2.0	0.8	26	0.8	2.0	2.2
28	0.4	2.0	0.8	28	0.6	2.0	1.2
30	0.5	2.0	1.0	30	0.6	2.0	1.2
31	0 (bank)	xxx	xxx	32	0.2	1.5	0.3
				32.5	0 (bank)	xxx	xxx
Total	10.9	30.5	21.9	xxx	12.7	31.3	25.3

* Distance of datum points along tape from one bank to the other.
§ In feet.
† In square feet.

Since all the partial cross-sections in this example are equal, an alternative method would be to compute the area of each section from the average depth and total width. For the upper cross-section, the average of the 15 depth measurements is 0.73 feet and the total width is 30.5 feet giving an area of 22.3 square feet. For the lower cross-section, the corresponding figures are: depth, 0.70 feet; width, 31.3 feet; and area, 24.7 square feet. In this case, the mean cross-sectional area of the stream would be 23.5 square feet.

Data for five float passages are given in Table 2. Applying the factor, 0.75, to the mean surface velocity gives the mean velocity of the stream, and multiplying this by the mean cross-sectional area (23.6 square feet) gives a discharge of 17.9 cubic feet per second.

Choice of location was found to be very important. Discharge readings taken in or immediately below riffles were quite erratic. Readings taken in the middle or lower parts of glides (velocities of 0.4 to 2.5 feet per second) corresponded surprisingly well with USGS gage readings. The constant, 0.75, was obtained empirically and could be

TABLE 2. HYPOTHETICAL DATA FOR FLOAT PASSAGES, ASSUMING 50 FEET BETWEEN TAPES

Distance from bank (feet)	Time (seconds)	Velocity (feet per second)
3	64	0.78
9	50	1.00
15	38	1.32
21	47	1.06
27	56	0.89
Mean surface velocity		1.01

expected to be valid only for streams having the same general characteristics as the test streams, i.e., moderate velocity, high width-to-depth ratio and a rubble-and-cobble substrate. It would no doubt differ in a deep stream, a sluggish stream or a stream having a bottom of fine gravel, sand, silt, clay or bedrock. Embody (1927) listed values of 0.8 and 0.9 for rough and smooth streambeds. It is not known how these constants were derived. In a rapid, turbulent, plunging stream, the method itself would probably be grossly inaccurate.

More accurate readings were obtained from 50-foot sections than from 25-foot sections. Standard deviations from USGS gage readings were 3.9 per cent (10 trials) and 5.4 per cent (5 trials), respectively. Several types of floats were tested. Any kind of float that protruded much above the surface of the water gave grossly inaccurate results whenever there was any wind. Plastic bags filled with dyed water tended to be driven to the bottom from time to time and to hang up momentarily on obstructions. Bottles partly filled with dyed water worked fairly well, but they were not easily spotted by the downstream worker. The painted "whiffle ball" was by far the most satisfactory float. A large number of float passages are not needed. On a stream 65 to 85 feet wide, the standard deviation from USGS readings was 3.9 per cent (10 trials) whether 5 or 10 float passages were used. When three float passages (midstream and halfway from midstream to each bank) were used, the standard deviation was 4.7 per cent. The float method is quite satisfactory for gaging any stream that has a suitable location for its use. It has the advantages of requiring a minimal amount of equipment and of being independent of stream chemistry, making it usable in streams receiving large and fluctuating amounts of chemical effluents from industrial and domestic sources. It has the disadvantages of requiring two workers and channel conditions that are not present in many streams.

SALT-DILUTION METHODS

Streams may be gaged accurately by salt-dilution methods if thorough mixing of salt and water can be obtained and if the downstream

concentration of salt can be accurately measured. The basic formula is as follows:

$$Q = \frac{R}{\Delta C}$$

where:

Q = discharge in cubic meters (millions of grams) per minute
R = the rate at which salt enters the stream in grams per minute
ΔC = increase in downstream concentration of salt in grams per million grams of water.

Since 1 cubic foot per second equals 1.7 cubic meters per minute, the formula $Q = \frac{R}{1.7\,\Delta C}$ yields discharge in cubic feet per second. If the salt is weighed in English units and R is computed in ounces per minute, the formula becomes $Q = \frac{R}{0.06\,\Delta C}$.

Some authors (Rouse, 1932; Cobb and Bailey, 1965) have listed more complex formulas making allowance for the small amount of water commonly added to the stream flow along with the salt. The precision obtainable in gaging streams by this method does not justify the use of these formulas.

In the European method described by Rouse, salt solution was introduced into the stream by means of a stainless steel Mariotte bottle, and chloride ion concentrations of samples taken above and below the salt-injection site were determined by silver nitrate titration. Since this titration is a delicate and time-consuming laboratory procedure that could not be done with any precision on the streambank, gaging results would not be immediately available to field workers.

A method described by Østrem (1964), and used in Scandinavia and Canada, makes use of a conductivity meter to determine relative salt concentration. Salt solution is not introduced at a constant rate, but is simply emptied into the stream from a 30- to 50-liter container. A worker at a downstream point takes conductivity readings at 5-second intervals. A sample drawn from the solution is saved and used to prepare a series of dilutions. Conductivity of the diluted samples is determined and plotted against their relative concentrations. This plot is used to convert stream conductivities to relative concentrations. The relative concentrations at the downstream station are plotted, and the area under the curve is determined with a planimeter. Discharge is then computed according to the formula

$$Q = \frac{V}{Aab}$$

where:

V = volume of salt solution
A = area under curve
a = time unit used on curve
b = concentration unit used on curve

The method is quite time-consuming and requires at least two workers. Østrem stated that about 3 hours are needed to gage a stream. Use of a direct conversion from specific conductivity to salt concentration greatly simplifies the procedure. The relationship between the molar concentration of sodium chloride solutions and their specific conductivity has been carefully worked out by physical chemists (Harned and Owen, 1958). At a given temperature, the relationship is almost linear for low concentrations, with specific conductivity increasing directly with concentration. However, as a result of attractive forces between ions (the Debye-Hückel effect), a specific conductivity at higher concentrations is less than would be predicted for a linear relationship.

At a given concentration, specific conductivity increases with increased temperature. The relationship given by Haskell (1954), who cited Pender (1922) as the source of the equation

$$\frac{L_2}{L_1} = \frac{4 + T_2}{4 + T_1}$$

where T_1 and T_2 are Fahrenheit temperatures[3] and L_1 and L_2 are the corresponding specific conductivities, is valid for all practical purposes between 15° and 45° C. Below 15° C. (59° F.), specific conductivities are significantly lower than would be predicted by Haskell's formula (Table 3).

TABLE 3. RELATIONSHIP OF SPECIFIC CONDUCTIVITY TO TEMPERATURE FOR SODIUM CHLORIDE SOLUTIONS

Temperature		Equivalent conductance *	Specific conductivity (percentage of 25° C. value)	
Centigrade	Fahrenheit		Actual	Predicted §
5	41	77.85	61.5	66
15	59	101.18	80	78
25	77	126.45	100	100
35	95	153.75	122	122
45	113	182.65	144	144

* Limiting value in very dilute solutions.
§ From formula of Haskell (1954).

Harned and Owen (1958) gave values for the equivalent conductance (specific conductivity in μmho/cm for each gram-equivalent of salt per milliliter of solution) for sodium chloride at various concentrations and temperatures (Table 4). Given a series of such values, it is

[3] For Celsius temperatures, a factor of 20 instead of 4 would be used.

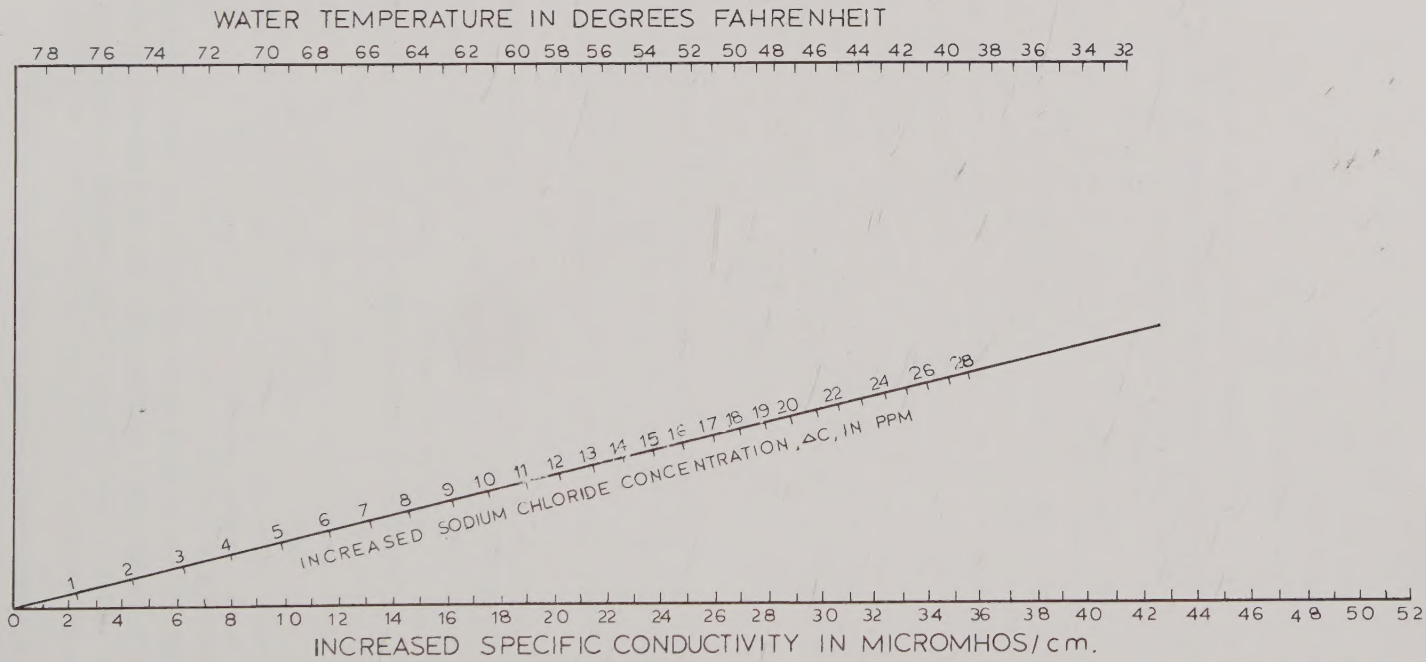

Figure 1. Nomograph for converting specific conductivity (up to 52 micromhos per centimeter) to ppm of sodium chloride. To determine concentration from specific conductivity, use straightedge to connect temperature (top scale) with specific conductivity (bottom scale) and read concentration on middle scale.

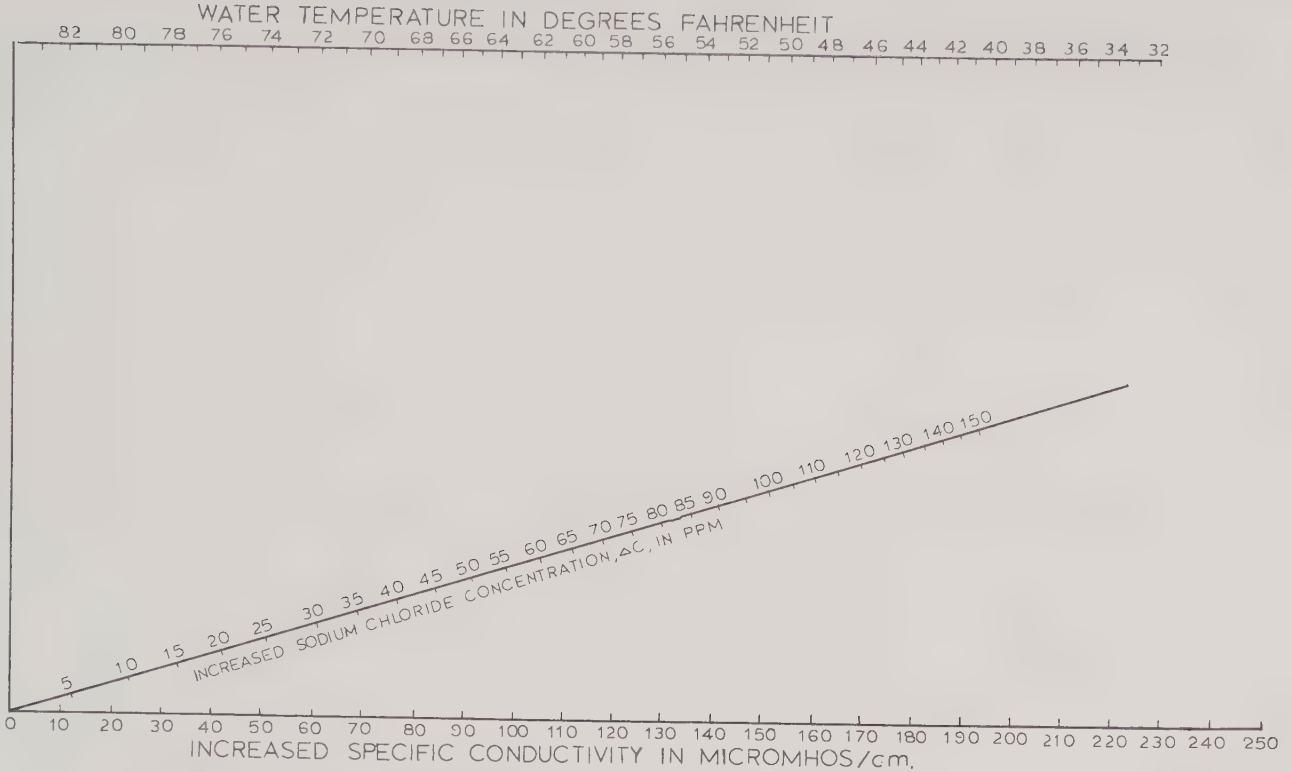

Figure 2. Nomograph for converting specific conductivity (up to 250 micromhos per centimeter) to ppm of sodium chloride. Read concentrations as in Figure 1.

TABLE 4. RELATIONSHIP OF SPECIFIC CONDUCTIVITY TO CONCENTRATION FOR SODIUM CHLORIDE SOLUTIONS AT 25° C. (77° F.) *

Concentration		Specific conductivity		
Normality	In ppm	μmho/cm/58.5 ppm ‡	μmho/cm/ppm	μmho/cm
→0	→0	126.45 §	2.161 §	0.5 °
0.0001	5.85	125.5	2.145	12.55
0.0005	29.25	124.5	2.128	62.24
0.001	58.5	123.7	2.114	123.7
	100.0†	123.3	2.107	210.7
	200.0†	122.0	2.085	417.0
	300.0†	121.0	2.067	620.0
	400.0†	120.0	2.051	820.4
	500.0†	119.0	2.034	1,017.0
0.01	585	118.51	2.025	1,184.6
	800	118.0	2.017	1,613.6
	1,000	117.0	2.000	2,000.0
0.1	5,850	106.74	1.824	10,670.0

* Adapted from Harned and Owen (1958).
§ Limiting value in very dilute solutions.
† Value obtained by interpolation.
‡ Equivalent conductance.
° Value for distilled water.

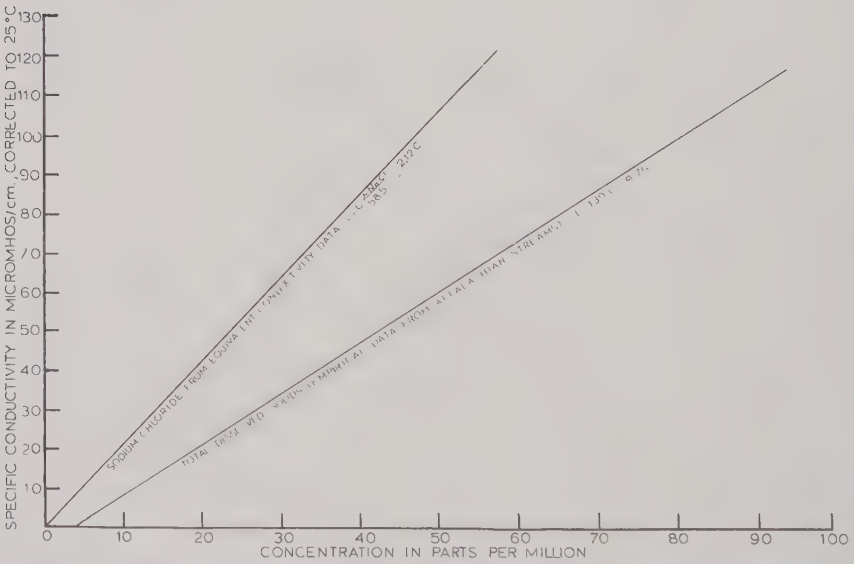

Figure 3. Specific conductivity-concentration relationships for sodium chloride and for naturally occurring salts in streams. From Harned and Owen (1958) and Lennon (1959).

possible to compute the sodium chloride concentration corresponding to a particular specific conductivity and temperature. However, it would be unhandy and tedious to do so in the field. Nomographs (Fig-

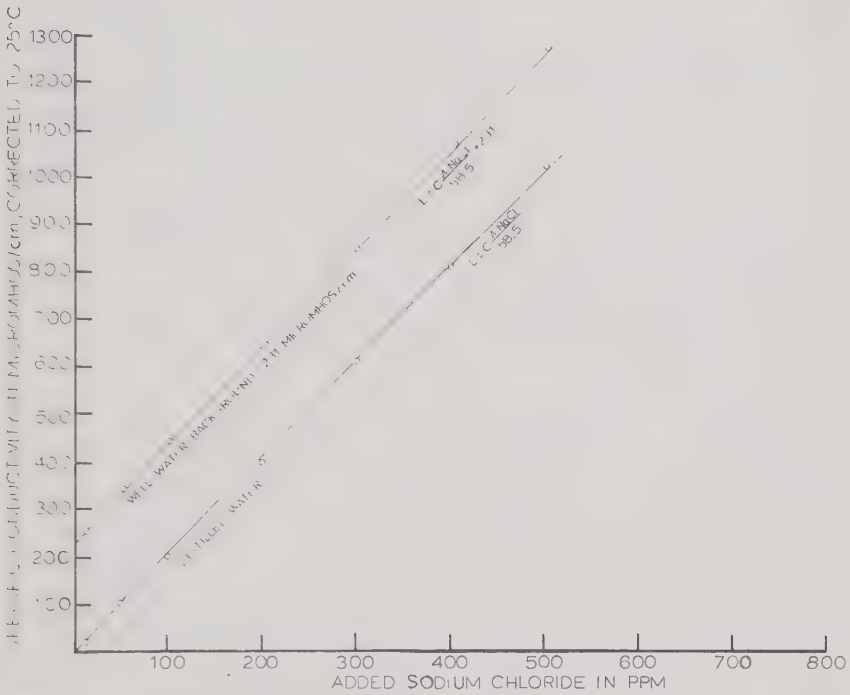

Figure 4. Specific conductivity-concentration relationships for sodium chloride in distilled water and well water. Lines represent theoretical values. Points are empirical readings taken on solutions of known concentration.

ures 1 and 2) were prepared, based on the data given by Harned and Owen (1958), enabling a field worker to determine the concentration of a sodium chloride solution from specific conductivity and temperature in a matter of seconds. It should be noted that the specific conductivity-concentration relationship for sodium chloride differs markedly from the empirical relationship determined by Lennon (1959) for the specific conductivity and total electrolyte content of Appalachian streams. Natural waters contain many dissolved salts which differ from each other both in formula weight and in equivalent conductance values (Figure 3).

Specific conductivities were determined, using a Beckman Model RA-2A stream conductivity meter,[4] for a series of prepared sodium chloride solutions of known concentration. The resulting data (Figure 4) corresponded remarkably well with theoretical values obtained from the equivalent conductances given by Harned and Owen (1958).

When well water having a specific conductivity of 231 μmho/cm was used instead of distilled water in preparing the solutions, the specific conductivities of these solutions differed from those of the pre-

[4] Beckman Instrument Company, Cedar Grove, New Jersey.

vious series by amounts approximately equal to this background specific conductivity. Thus it is a legitimate procedure to determine the background specific conductivity in a stream, introduce salt, take specific conductivity readings downstream and subtract the background from the downstream reading to obtain the increased specific conductivity due to the added salt. The nomograph can then be used to convert this figure to the parts per million of added salt (ΔC). Accuracy of the nomograph over a wide temperature range was confirmed experimentally. A salt solution having a specific conductivity of 66 μmho/cm at 68° F. was chilled to 32° F. Fifteen specific conductivity readings taken at different temperatures within this range all converted to 34 ppm sodium chloride.

The Mariotte bottle technique proved most suitable for measuring the discharge of small streams and turbulent streams up to about 50 cubic feet per second, although there is no theoretical reason why a much larger stream could not be gaged using a battery of bottles. Equipment, consisting of the Beckman stream conductivity meter, the Mariotte bottle, a laboratory stool, tripod or other small platform, a carpenter's level and a thermometer, is light-weight, easily portable and less expensive than a Price current meter. The Beckman meter registers specific conductivity directly in μmho/cm when the electrode probe is placed in the stream. In swift water, the probe may be allowed to rest against the upstream side of the operator's boots. The body of the meter is not completely waterproof and should be encased in a plastic bag held by a rubber band around the cord to the electrode. The procedure is as follows:

1. Select a site where there is a sharply constricted riffle, a shallow and relatively swift eddy, a cascade or some other good source of turbulent mixing. However, this is important only on fairly wide streams; on small streams up to about 15 feet wide, almost any site will work. Large deep pools with slow circulation should be avoided.
2. Set up the stool in midstream above the site, and level the top.
3. Using Table 5 as a guide, place an appropriate amount of salt in the Mariotte bottle. Set the bottle on the stool, fill it to the desired level with stream water and stir the salt into solution with a length of wooden dowling or other stirring rod. Screw the top tightly in place. If there is some general idea of the amount needed, salt may be pre-weighed in the laboratory and packaged in plastic freezer bags for field use. Since reliable results can be obtained from introduction rates varying from about 150 to 3,000 grams for each cubic foot per second of flow, one size package will handle quantities for a wide variety of streams.

4. Measure the water temperature and background specific conductivity.
5. Open the outlet valve of the Mariotte bottle and record the time. The salt solution will now flow into the stream at a constant rate.
6. Go to a convenient point downstream (preferably at a channel constriction with good velocity at both banks) and determine the specific conductivity. As the salt solution arrives, the readings will increase rapidly and then level off to a plateau. If, after a few minutes, the readings are not constant from bank to bank, move downstream to a point where mixing is more complete. The necessary distance can vary from 50 to 1,000 feet below the introduction point, depending on stream conditions. Where mixing is inadequate, it may be necessary to use the mean of a set of readings taken at equal intervals across the stream. However, this procedure should not be attempted where deviations are more than about 3 μmho/cm.
7. Record the time when the flow of salt solution stops.
8. Measure the temperature and background again.
9. Compute the discharge. The following is an example, using hypothetical data:

   Weight of salt = 6,000 grams
   Time = 20 minutes

$$R = \frac{6{,}000 \text{ grams}}{20 \text{ minutes}} = 300 \text{ grams per minute}$$

   Temperature = 60° F.
   Background specific conductivity = 30 μmho/cm
   Downstream specific conductivity = 44 μmho/cm
   Increase in specific conductivity = 14 μmho/cm
   ΔC (from nomograph; 14 μmho/cm and 60° F.) = 8.1 ppm

$$Q = \frac{R}{1.7\Delta C} = \frac{300}{1.7(8.1)} = 21.8 \text{ cubic feet per second}$$

Tests showed that good mixing within 200 feet could be obtained on any riffle-and-pool stream from a trickle to a width of about 15 feet. Wider streams, up to about 50 cubic feet per second discharge, can be gaged by this method wherever there are sites with good turbulent mixing. Adequate mixing did not occur in wide, shallow reaches of streams even where rocks and high velocities created a good deal of turbulence. The method was used successfully on a very sluggish stream having a width of about 12 feet, a mean depth of about 2.5 feet and a discharge of less than 1 cubic foot per second. However, in a stream of this type, the salt solution should not be introduced immediately above a depression in the stream bottom, since part of the dense solution accumulates in the depression rather than moving immediately

Table 5. Recommended Rates of Salt Introduction for Gaging Stream Discharge by the Mariotte Bottle Method

Estimated flow		Bottle *		Time for bottle to empty (minutes)	Sodium chloride (grams)	Rate of solution (gr/min)	Anticipated specific conductivity (μmho/cm)
Gallons per minute	Cubic feet per second	Size (gallons)	Aperture (inches)				
Moderate to rapid streams and seepages							
3–5		5	7/32	20	20	1	65–220
5–50		5	1/4	15	20	1.5	11–220
45–450	1–1	5	1/4	15	200	15	10–220
	1–10	5	1/4	15	2,000	150	10–195
	10–20	13	11/32	20	6,000	300	10–42
	20–50	13	13/32	15	7,500	500	6–33
Sluggish streams, springs feeding into pools, etc.							
1–10		5	1/8	60	20	0.33	12–220
10–100	0.02–0.2	5	1/8	60	200	3.3	12–220
	0.2 –2	5	1/8	60	2,000	33	12–220
	2 –8	13	13/64	60	6,000	100	8–65
	8 –15	13	13/64	60	7,500	125	7–22

* Bottle with 46-millimeter head.

downstream. In sluggish streams the salt concentration builds up to a plateau very gradually, so it is best to set the Mariotte bottle to run out in 60 minutes.

Comparison with USGS gage readings showed that this method was the most precise of those tested. Standard deviation from gage readings was 3.8 per cent (7 trials). Maximum deviations were +6.5 and −6.6 per cent.

Salt-dilution gaging, using a Mariotte bottle, has the advantages of high precision and of applicability to small, shallow and turbulent streams. One worker can gage a stream unaided, and field calculations are rapid and simple. It can be used to gage extremely small flows in springs, seepages and hatchery raceways. The method is particularly appropriate for use in conjunction with chemical stream reclamation, since a Mariotte bottle may be used to introduce the fish toxicant, and a conductivity meter and a bolt of salt solution are commonly used to study the pattern of downstream movement and dilution of the toxicant. It has the disadvantage of not being usable in wide, shallow streams. With the Beckman RA-2A meter, it would be difficult to use in hard-water streams with high background specific conductivities, since at high background levels it is harder to detect and measure small changes in specific conductivity. The method would not be accurate in a stream where background specific conductivity fluctuated rapidly as a result of irregular release of industrial effluents.

A second salt-dilution method was developed for use in wide, shallow streams. It differs from the previous method in that salt is

introduced as salt blocks rather than as a solution. The procedure is as follows:

1. Weigh a lot of at least five salt blocks (4-pound plain salt blocks obtained from any feed store work admirably). The amount needed is roughly 20 pounds (9 kilograms) for streams having discharges of less than 20 cubic feet per second, and 1 pound (450 grams) for each cubic foot per second of discharge in larger streams.
2. Select a relatively shallow riffle with reasonably uniform depth. Determine the water temperature and background specific conductivity.
3. Distribute the salt blocks across the riffle in rough proportion to the distribution of discharge. Do not place blocks in sluggish side-pockets. Ordinary 3-gallon plastic buckets work well for carrying blocks. Record time or start stopwatch when half of blocks are in water. Release of salt from the blocks will be proportional to the stream velocity and the surface area of the blocks. Rate of solution will not be a constant, but will slowly decrease as the blocks are left in the stream.
4. Move downstream about 100 feet and take a series of specific conductivity readings across the stream. If the readings deviate more than about 2 μmho/cm, redistribute the blocks to give more uniform readings. The blocks will ordinarily be left in the stream for 10 to 30 minutes. For a 20-minute run, take a series of specific conductivity readings at approximately 5, 10 and 15 minutes after placement of the blocks. Six readings at equal intervals across the stream are adequate.
5. Remove the blocks and record time or stop stopwatch when half of the blocks are removed.
6. Redetermine the temperature and background specific conductivity.
7. Reweigh the blocks and determine the loss of weight.
8. Compute the stream discharge. The following is an example using hypothetical data:

   Weight of salt used (i.e., weight loss of blocks) = 8,000 grams
   Time = 20 minutes

   $$R = \frac{8{,}000 \text{ grams}}{20 \text{ minutes}} = 400 \text{ grams per minute}$$

   Temperature = 48° F.
   Background specific conductivity = 50 μmho/cm
   Downstream specific conductivity = 69 μmho/cm
   Increase in specific conductivity = 19 μmho/cm
   ΔC (from nomograph: 19 μmho/cm and 48° F.) = 13.0 ppm

   $$Q = \frac{B}{1.7\Delta C} = \frac{400}{1.7(13)} = 18.0 \text{ cubic feet per second}$$

Table 6. Comparison of Stream-gaging Methods

Suitable sites	Advantages	Disadvantages	Deviation from USGS gage readings (per cent)
		Float	
Streams of from 5 to 150 cubic feet per second in mid or lower part of glide with parallel banks, depth of less than 2.5 feet (wadeable), velocity of 0.3–2.5 feet per second and rubble bottom without protruding rocks	No expensive equipment needed; independent of stream chemistry	Suitable sites often not available; cannot be used on rocky, turbulent streams; requires two workers; relatively large amount of computation needed	3.8 + 7.7 − 3.3
		Salt dilution (Mariotte bottle)	
From a trickle up to 50 cubic feet per second; almost anywhere in narrow streams; above site of strong turbulent mixing in wider streams	Precise; can be used in small and turbulent streams; requires only one worker; easy computations	Cannot be used in wide, shallow streams, or streams with very high or rapidly fluctuating electrolyte content	3.8 + 6.5 − 6.6
		Salt dilution (salt block)	
Streams of from 1 to 75 cubic feet per second; almost any site, but shallow riffle preferred	Can be used almost anywhere; requires only one worker; easy computations	Lower precision; cannot be used in streams with very high or rapidly fluctuating electrolyte content; need for reweighing salt blocks	6.0* +15.0 −11.0

* Value for wide, shallow, non-turbulent streams; turbulent mixing would probably increase precision.

The method can be adapted for use in deep sluggish streams by suspending the blocks in mesh bags from a bridge or from a line stretched across the stream. If the blocks are placed on the bottom in such streams, the result is an accumulation of dense brine on the bottom in the immediate vicinity of the blocks.

This method has a greater number of built-in sources of error than the previous method, and it might be expected to be somewhat less precise. Comparison with USGS gage readings yielded a 6.0 per cent standard deviation for 15 tests. Maximum deviations from gage readings were +15.0 and −11.0 per cent. However, 7 of the 15 tests had deviations of less than 2 per cent from gage readings. In comparing these results with those from the other two methods, it should be noted that most of the salt-block tests were run at "difficult" sites where neither of the other methods could have been used. This method has the advantage of being usable in practically any type of stream up to about 75 cubic feet per second of discharge. One worker can easily gage a stream. Disadvantages include the relatively low precision and the necessity of either setting up a high-capacity balance near the gaging site or bringing the salt blocks back to the laboratory for re weighing. It is subject to the same chemical limitations as the previous method.

DISCUSSION

The three methods tested are essentially complimentary. Their characteristics are compared in Table 6. If a stream has sites with moderate gradient, low turbulence, velocities above about 0.1 foot per second and prevailing depths greater than 7½ inches, the standard and thoroughly tested current-meter method is the best choice. In the absence of a current meter, either the float method or one of the salt-dilution methods is a satisfactory substitute. In wide, shallow streams without suitable sites for the float method, the salt-block method is appropriate. The Mariotte bottle method is superior for very small streams and for swift, turbulent rocky streams. In very sluggish streams, the choice of a Mariotte bottle or suspended salt blocks will depend on the width of the stream.

LITERATURE CITED

BUCHANAN, T. J., AND W. P. SOMERS. 1965. Discharge measurements at gaging stations. U.S. Geol. Survey, Surface Water Technique Series, Book 1, Chap. 11: 1–67.

CARTER, ROLLAND W., AND IRVING E. ANDERSON. 1963. Accuracy of current meter measurements. Jour. Amer. Soc. Civ. Eng., Hydraulics Div., 89 (4, Part 1): 105–115.

COBB, E. D., AND J. F. BAILEY. 1965. Measurement of discharge by dye-dilution methods. U.S. Geol. Survey, Surface Water Technique Series, Book 1, Chap. 14: 1–27.

EMBODY, G. D. 1927. An outline of stream study and the development of stocking policy. Contr. Agr. Lab., Cornell Univ.

Engstrom-Heg, Robert. 1971. A light-weight Mariotte bottle for field, laboratory and hatchery use. Prog. Fish Cult. 33(4):227–231.

Harned, Herbert S., and Benton B. Owen. 1958. The Physical Chemistry of Electrolytic Solutions. Reinhold Publ. Corp. New York, N.Y.

Haskell, David D. 1954. Electrical fields as applied to the operation of electrical fish shockers. N.Y. Fish and Game Jour. 1(2):130–170.

Lennon, Robert E. 1959. The electrical resistivity meter in fishery investigations. U.S. Fish and Wildl. Serv., Spec. Sci. Rpt., Fish No. 287.

Østrem, Gunnar. 1964. A method of measuring turbulent streams. Geogr. Bull. 21: 21–43.

Pender, Harold. [ed.] 1922. Handbook for Electrical Engineers. John Wiley and Sons, New York, N.Y.

Pierce, C. H. 1942. Methods of stream gaging. In: Physics of the Earth, Vol. 9 "Hydrology" [O. E. Meinzer, ed.], McGraw-Hill Book Co.: 486–498.

Rouse, Hunter. 1932. Research institute for hydraulic engineering and water power. Trans. Amer. Soc. Mech. Eng., Hydraulic Section, 54(3):27–40.

Welch, Paul S. 1948. Limnological Methods. The Blakiston Co., Philadelphia, Pa.

MIGRATION, RATE OF EXPLOITATION AND MORTALITY OF SCUP FROM THE INSHORE WATERS OF EASTERN LONG ISLAND[1]

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ABSTRACT

A total of 3,769 scup were tagged in the Peconic Bays during the spring and summer in 1965 and 1966. Recoveries of 693 scup showed that almost 33 per cent were taken by sport fishermen and more than 66 per cent were caught by commercial fishermen. Recovery locations extended from Georges Bank off Massachusetts to Nags Head in North Carolina and suggest a north-south and inshore-offshore seasonal migration. Scup tagged during the summer exhibited an average exploitation rate of approximately 15 per cent, an annual natural mortality rate of approximately 80 per cent and a total annual mortality rate of approximately 95 per cent. It is concluded that, although harvesting a greater proportion of young fish would represent better use of the resource, lowering the legal size limit (presently 7 inches) would not be practical because the smaller fish would not be marketable.

Because of its value to the commercial and sport fisheries of New York, an investigation of several aspects of the life history of the scup (*Stenotomus chrysops*) was undertaken as a basis for sound management. Studies of age and growth and age at maturity were published previously (Finkelstein, 1969a, 1969b). The present paper deals with the migration, rate of exploitation and mortality of scup as determined from tag and recapture data.

A review of the available published literature revealed few previous studies of scup movements and migration. Goode (1884) and Bean (1903) discussed movements so far as their observations permitted. Nesbit and Neville (1935) reported an annual scup migration in the fall from summer fishing grounds off southern New England and New Jersey to winter fishing grounds off the Virginia capes, and a return migration in the spring from the winter grounds to the summer area. Dickerson (1939), Bigelow and Schroeder (1953), Anonymous (1962), Neville and Talbot (1964) and Smith and Norcross (1968) provided additional data on movements and locations of both commercial and sport fishery exploitation.

TAG EVALUATION

Although earlier investigations (Perlmutter, 1960; Cogswell, 1962) suggested that the Petersen disc tag was favorable for use on scup, additional experimentation was judged necessary to substantiate its suitability.

Two floating live cars, each 5 feet long by 3 feet wide by 2½ feet

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R, representing Contribution No. 71-4 of the Division of Marine and Coastal Resources.

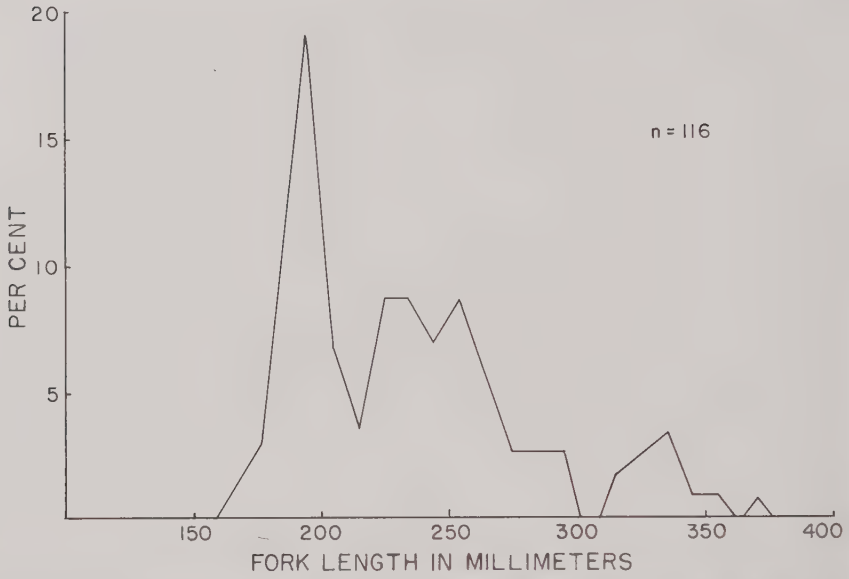

Figure 1. Length-frequency distribution of scup used in tag-testing experiment.

high, were constructed and placed in the Suffolk County Boat Basin at Shinnecock Canal in June 1964, and 58 trawl-caught scup were placed in each car. The size distribution of these fish, which ranged from 155 to 375 millimeters in fork length, is shown in Figure 1. Half of those in each car were selected randomly and tagged through the middorsum approximately 25 millimeters below the dorsal fin. The tag used consisted of two cellulose acetate discs (one red and one serially numbered white), each 0.5-inch in diameter by 0.025-inch in thickness, affixed through the body musculature by a 1.75-inch by 0.035-inch flathead stainless steel pin.

The fish were fed approximately three times each week with a variety of vertebrate and invertebrate foods. The condition of tags and fish was observed periodically. In mid-October the experiment was terminated, the tags were removed and the survivors were released. Differences between the proportion of deaths among tagged and untagged specimens, both within and between cars, were treated statistically by means of "*t*" tests.

At the time the experiment was terminated, 51 specimens (25 tagged and 26 untagged) in one car and 36 specimens (15 tagged and 21 untagged) in the other car remained alive. The losses, however, were not due entirely to mortality; some specimens were stolen and one fish escaped. It was, therefore, necessary to readjust the initial population numbers in each car to compensate for these unexpected losses.

The adjusted initial populations were 29 tagged and 26 untagged fish in one car and 24 tagged and 29 untagged fish in the other.

Tests between the proportions of tagged vs. untagged fish in each car at the beginning and at the end of the experiment yielded differences which were not significant ($t = 0.38$; 0.34). A test between the final proportions of tagged vs. untagged fish in each car yielded similar results ($t = 1.08$). These results suggest that scup marked with Petersen disc tags survive as well as non-tagged individuals. No tags were shed during the experiment.

MIGRATION, EXPLOITATION, AND MORTALITY

From May 11 to 27 and July 7 to 22 in 1965 and from May 12 to 26 and July 11 to September 29 in 1966, scup were collected by otter trawl in Great and Little Peconic Bays of eastern Long Island. The gear and methods employed were described previously by Finkelstein (1969a). Each scup was measured to the nearest 5 millimeters in fork length and tagged with Petersen discs. The tags and tagging methods were the same as those employed in the tag evaluation experiment. All tagged fish were released in the same general vicinity in which they were captured. A $1.00 reward was offered for the return of both tag discs, along with the following information: date, location and method of capture.

A total of 3,769 scup were tagged during the study. Size distributions of these specimens are presented in Figures 2 and 3 for each tagging period. For ease of presentation and analysis, fish tagged in both years were combined into single spring and summer groups.

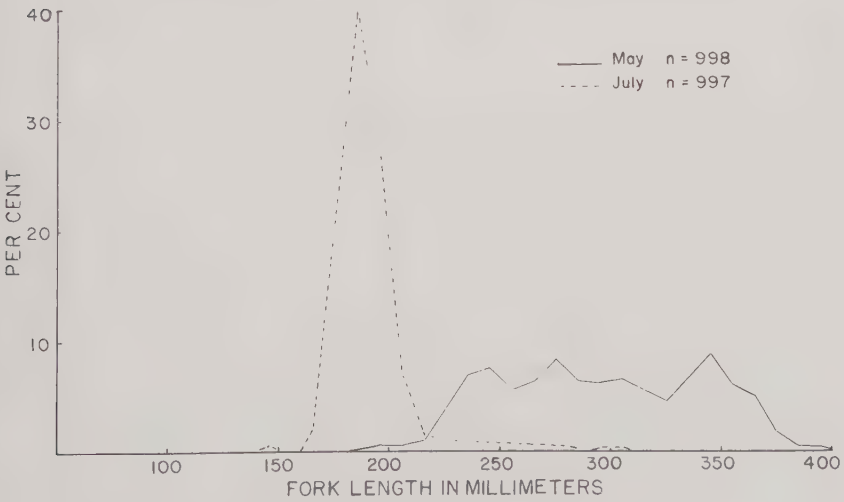

Figure 2. Length-frequency distribution of scup tagged in 1965.

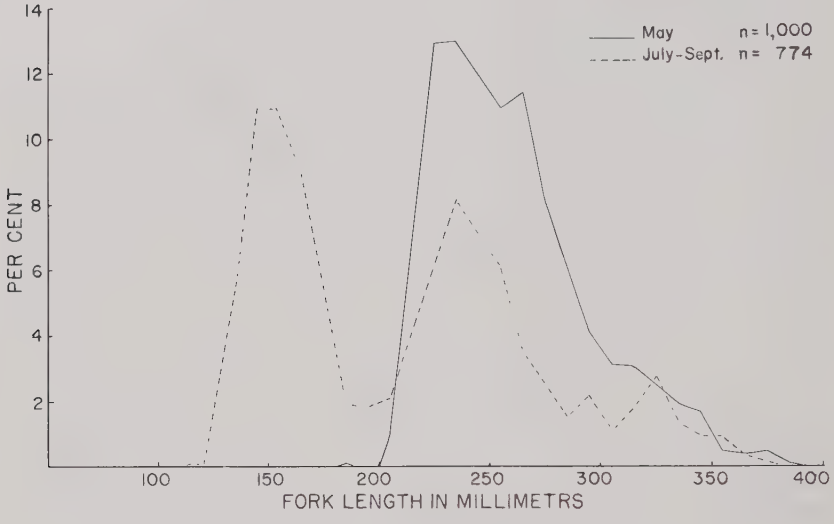

Figure 3. Length-frequency distribution of scup tagged in 1966.

Recovery records are presented separately for spring and summer tagging according to manner of recovery in Table 1. Results indicate that nearly 33 per cent of the returns were received from the sport fishery, while the remainder were taken by the commercial fishery. A test between the proportion of sport vs. commercial fishery recoveries for fish tagged in spring, and a similar proportion for fish tagged in summer, revealed a highly significant difference ($t = 5.68$).

The location and season of recovery for tagged scup are presented in Tables 2 and 3 and illustrated in Figures 4 to 11. Locations extended from Georges Bank off Massachusetts to Nags Head in North Carolina.

For fish tagged in May in 1965 and 1966 (Table 2), most spring recoveries (55 per cent) were made in offshore waters from New Jersey to North Carolina, while only 14 per cent were made in the adjoining inshore waters. The remainder (31 per cent) of the spring recoveries were from the inshore waters of New York, Connecticut, Rhode Island and Massachusetts. Nearly all summer recoveries (98 per cent) came from the inshore waters of New York and southern New England, and the remainder were from the inshore waters of New Jersey. During the fall, recoveries from the inshore waters of New York and southern New England constituted the major proportion (76 per cent) of returns. Additional recoveries were made in inshore (7 per cent) and offshore (11 per cent) waters of New Jersey, and in offshore waters of Maryland, Virginia and North Carolina (6 per cent). In the winter, there were no recoveries from areas north of New Jersey, and less than 2 per

TABLE 1. RECOVERIES OF SCUP TAGGED IN THE PECONIC BAYS ACCORDING TO SEASON TAGGED AND MANNER OF RECOVERY

Manner of recovery	Number	Per cent
Tagged during spring *		
Sport fishery (hook and line)	155	42.5
Commercial fishery		
Haul seine	39	10.7
Pound net and floating trap	24	6.6
Otter trawl	140	38.4
Gill net	2	0.5
Market †	3	0.8
Sub-total	208	57.0
Unknown ‡	2	0.5
Total	365	100.0
Tagged during summer §		
Sport fishery (hook and line)	73	22.3
Commercial fishery		
Haul seine	14	4.3
Pound net and floating trap	22	6.7
Otter trawl	214	65.2
Gill net	0	0.0
Market †	3	0.9
Sub-total	253	77.1
Unknown ‡	2	0.6
Total	328	100.0
Spring and summer combined		
Sport fishery (hook and line)	228	32.9
Commercial fishery		
Haul seine	53	7.6
Pound net and floating trap	46	6.6
Otter trawl	354	51.1
Gill net	2	0.3
Market †	6	0.9
Sub-total	461	66.5
Unknown ‡	4	0.6
Total	693	100.0

* Spring: May 11–27 in 1965, May 12–26 in 1966; number tagged = 1,998.
§ Summer: July 7–22 in 1965, July 11–September 29 in 1966; number tagged = 1,771.
† Tags returned from commercial fish markets, information on recovery unavailable.
‡ Tags returned from individuals, information on recovery unavailable.

cent came from the inshore waters of that state. More than 30 per cent of the winter recoveries, however, came from offshore waters of New Jersey and Delaware, while nearly 56 per cent were from offshore waters of Maryland, Virginia and North Carolina. A small percentage (12 per cent) were recovered from the inshore waters of the latter three states.

The seasonal patterns of returns for scup tagged during July in 1965 and from July to September in 1966 were similar to those for scup tagged in May (Table 3).

Comparison of the length-frequency distributions of recovered

Figure 5. Summer recovery locations for scup tagged during May in 1965 and 1966.

Figure 4. Spring recovery locations for scup tagged during May in 1965 and 1966.

Figure 6. Fall recovery locations for scup tagged during May in 1965 and 1966.

Figure 7. Winter recovery locations for scup tagged during May in 1965 and 1966.

Figure 8. Spring recovery locations for scup tagged during July in 1965 and from July to September in 1966.

Figure 9. Summer recovery locations for scup tagged during July in 1965 and from July to September in 1966.

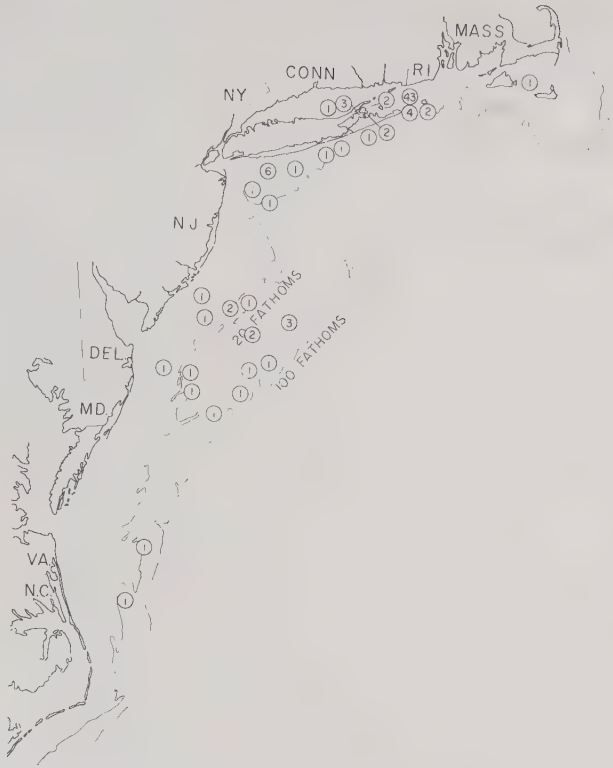

Figure 10. Fall recovery locations for scup tagged during July in 1965 and from July to September in 1966.

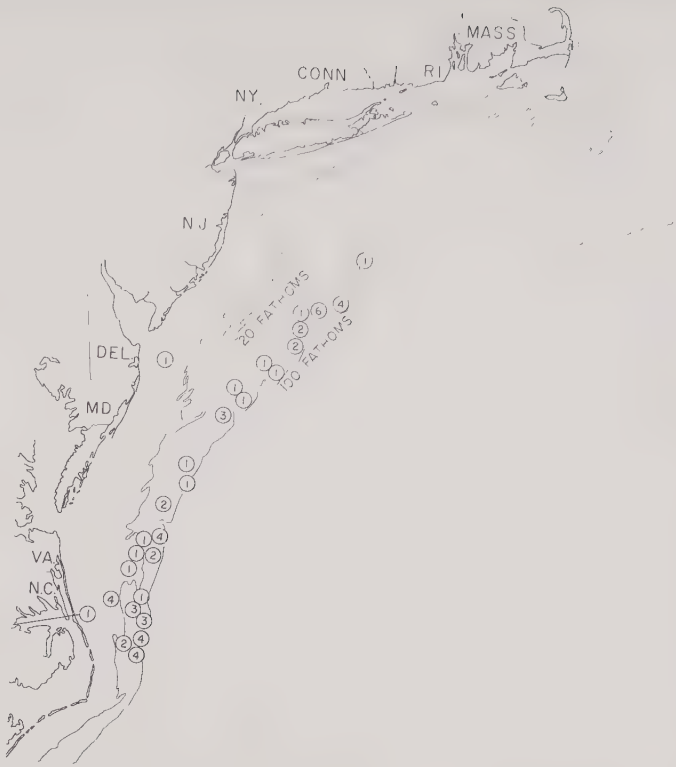

Figure 11. Winter recovery locations for scup tagged during July in 1965 and from July to September in 1966.

TABLE 2. LOCATIONS ACCORDING TO SEASON FOR RECOVERIES OF SCUP TAGGED IN THE PECONIC BAYS DURING MAY IN 1965 AND 1966

Location	Season *							
	Spring		Summer		Fall		Winter	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
New York, Connecticut, Rhode Island and Massachusetts								
Inshore §	16	31.4	116	97.5	68	76.4	0	0.0
Offshore †	0	0.0	0	0.0	0	0.0	0	0.0
New Jersey and Delaware								
Inshore §	4	7.8	3	2.5	6	6.8	1	1.7
Offshore †	19	37.2	0	0.0	10	11.2	18	30.5
Maryland, Virginia and North Carolina								
Inshore §	3	5.9	0	0.0	0	0.0	7	11.9
Offshore †	9	17.6	0	0.0	5	5.6	33	55.9
Total	51	100.0	119	100.0	89	100.0	59	100.0

* According to celestial calendar, i.e., spring = March 21–June 21, etc.
§ Inshore = within the 20-fathom curve.
† Offshore = beyond the 20-fathom curve.

TABLE 3. LOCATIONS ACCORDING TO SEASON FOR RECOVERIES OF SCUP TAGGED IN THE PECONIC BAYS FROM JULY TO SEPTEMBER IN 1965 AND 1966

Location	Season *							
	Spring		Summer		Fall		Winter	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
New York, Connecticut, Rhode Island and Massachusetts								
Inshore §	85	75.2	142	97.3	28	38.9	0	0.0
Offshore †	0	0.0	0	0.0	1	1.4	0	0.0
New Jersey and Delaware								
Inshore §	5	4.4	4	2.7	26	36.1	0	0.0
Offshore †	9	8.0	0	0.0	15	20.8	13	50.0
Maryland, Virginia and North Carolina								
Inshore §	11	9.7	0	0.0	0	0.0	2	7.7
Offshore †	3	2.7	0	0.0	2	2.8	11	42.3
Total	113	100.0	146	100.0	72	100.0	26	100.0

* According to celestial calendar, i.e., spring = March 21–June 21, etc.
§ Inshore = within the 20-fathom curve.
† Offshore = beyond the 20-fathom curve.

scup (Figures 12 and 13) and the length-frequency distributions of the total sample at the time of tagging (Figures 2 and 3) suggested nonconformity in several cases. Since equal availability is one of the underlying assumptions that must be satisfied for valid estimates of mortality and exploitation, the observed differences were subjected to more

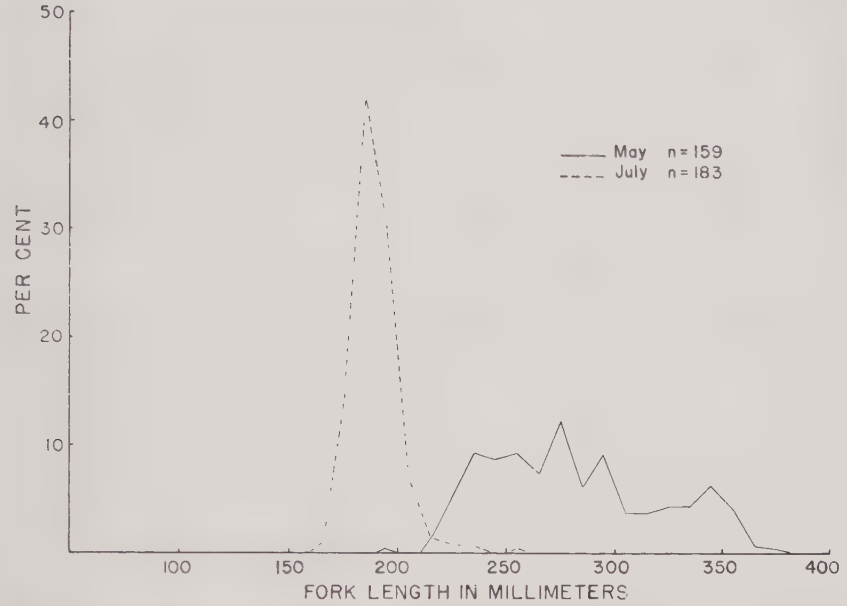

Figure 12. Length-frequency distribution of recovered scup that had been tagged in 1965, according to time of tagging.

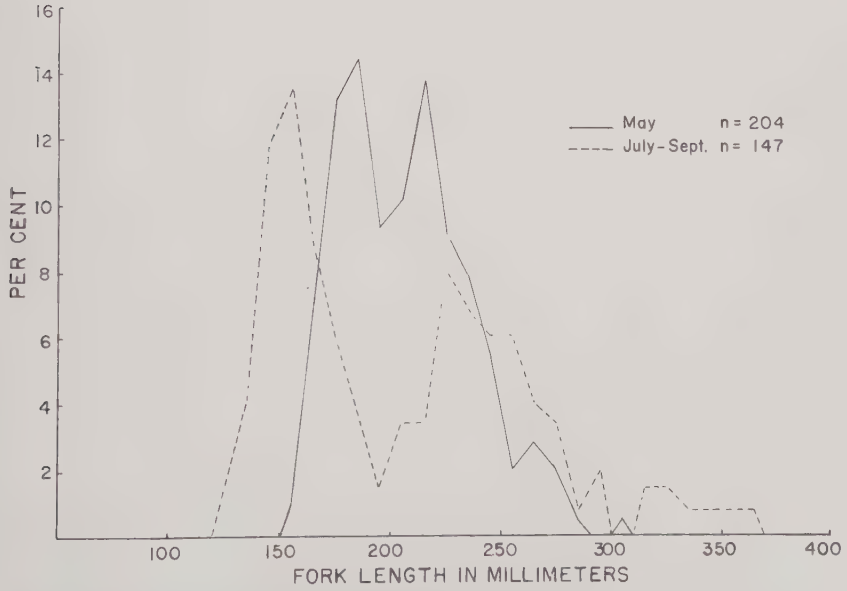

Figure 13. Length-frequency distribution of recovered scup that had been tagged in 1966, according to time of tagging.

critical scrutiny by chi square analysis. The results indicate that significant differences in length frequency occurred between tagging and recovery for fish tagged in the spring ($\chi^2 = 21.18$; 6.74), but no significant differences were detected for fish tagged during the summer ($\chi^2 = 1.99$; 4.33). For this reason, meaningful estimates of mortality and rate of exploitation could be made for the summer-tagged scup only. All other assumptions (Ricker, 1958), were considered reasonably satisfied for practical purposes of calculation.

The data revealed that scup tagged during the summer in the Peconic Bays exhibited an average exploitation rate of approximately 15 per cent, an annual natural mortality of approximately 80 per cent and a total annual mortality of approximately 95 per cent (Table 4).

DISCUSSION AND CONCLUSIONS

The recovery records suggest a north-south and inshore-offshore seasonal migratory pattern similar to that indicated by earlier authors. The data reveal that scup tagged in New York waters winter, for the most part, in offshore waters between New Jersey and North Carolina. With the approach of spring, the fish begin to migrate northward and inshore toward New Jersey, New York and southern New England. They remain in these waters throughout summer and early fall after which a reverse migration begins to the offshore wintering grounds.

Because scup are concentrated and are easily accessible to sport fishermen in the Peconic Bays during the spring, exploitation by such fishermen is at its peak during this season. Briggs (1968) found the catch per effort to be greatest in May. At that time, commercial fishing is limited to a small number of haul seines and only a few pound nets operation of which ordinarily does not begin until June. Otter trawling, the most efficient method for collecting scup, is prohibited in the Peconics between April 15 and October 1. Conceivably, the greater sport fishing pressure in the spring, coincident with light commercial fishing, may account for the greater proportion of hook-and-line catches of spring-tagged scup as compared with summer-tagged fish. Furthermore, the arrival of other important sport fish such as northern kingfish, weakfish, northern puffer and bluefish, and the tendency of scup to scatter throughout the Peconic Bays and into Gardiners Bay as the summer progresses, may be additional factors in causing lower catches of scup by sport fishermen after the spring season.

The high rate of natural mortality calculated from the tag and recapture observations suggests that, biologically, the scup resource in New York could probably be best used by harvesting the fish at an early age. This conclusion is supported by weight yields, interpolated from data reported by Briggs (1968) and Finkelstein (1969a), of a hypothetical scup population subjected to an annual mortality rate of 80

Table 4. Estimated Rates of Survival, Mortality and Exploitation for Scup Tagged During the Summer in 1965 and 1966

Year	Fish tagged			Fish recovered			Survival * (per cent)	Annual total mortality (per cent)	Exploitation § (per cent)	Annual natural mortality (per cent)
	Total number	Recovered during tagging period	Number used for calculation	1st year (R_1)	2nd year (R_2)	3rd year (R_3)				
1965	997	9	988	162	12	0	7	93	16	77
1966	774	34	740	111	2	0	2	98	15	83

* Survival between years (s) derived from formula $s = \dfrac{R_2 + R_3 + \cdots + R_n}{R_1 + R_2 + \cdots + R_{n-1}}$

in which:

R_1 = recoveries in year of tagging.
R_2, R_3 etc. = recoveries in later years.

§ Exploitation (u), i.e., fishing mortality, derived from formula $u = \dfrac{R_1 + R_2 + \cdots R_n}{M(1 + s + s^2 + \cdots s^{n-1})}$

in which:

M = number of tagged fish used for calculation.
s = survival between years.

Table 5. Calculated Change in Total Weight of 1,000 Scup (sexes combined) Sustaining Annual Mortality of 80 Per Cent * for Four Years

Age (years)	Individual fish		Population	
	Average length (millimeters)	Average weight (grams)	Number	Weight (grams)
1	106.5	29.7	1,000	29,700
2	161.2	98.6	200	19,720
3	204.0	194.9	40	7,796
4	237.3	301.9	8	2,415
5	263.5	408.9	2	8.8

* Equivalent to the rate of natural mortality observed.

per cent (Table 5). Maximum yield (in weight) is attained when scup are harvested at an age of only 1 year and at a size of approximately 4 inches (106.5 millimeters) in fork length. Although scup are not yet mature at this age (Finkelstein, 1969b), it seems doubtful that exploitation at that time would be harmful to the future abundance of the species. This is corroborated by previous observations which indicate that past fluctuations in production have been related primarily to environmental conditions rather than to the size of the spawning population (Neville and Talbot, 1964).

It is doubtful, however, that reducing the minimum legal size at which scup may be bought and sold in New York from the present 7 inches (177 millimeters) in total length to 4 inches in fork length would be of much benefit. For the most part, scup less than 7 inches long would probably be unacceptable to the commercial market as it now exists in the New York area. Furthermore, although there is no size limit for sport fishing, scup less than 6 inches long are seldom retained by sport fishermen (Briggs, 1968).

Therefore, although sacrificing an approximate yield in total weight of 33 per cent, i.e., the loss from natural mortality between ages 1 and 2 as illustrated in Table 5, these data indicate that the present size limit for scup trafficked in commercially is appropriate.

LITERATURE CITED

Anonymous. 1962. The porgy in Raritan Bay. A brief summary of its life history and importance to the commercial and sport fishery. New Jersey Div. Fish and Game, Fish Res. and Dev. Sect. Admin., Rep. No. 2. (mimeo.)

Bean, Tarleton, H. 1903. Catalogue of the fishes of New York. N. Y. S. Mus. Bull. 60, Zool. 9.

Bigelow, Henry B., and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. U. S. Fish and Wildl. Serv. Bull. 74.

Briggs, Philip T. 1968. The sport fisheries for scup in the inshore waters of Long Island. N. Y. Fish and Game Jour. 15(2):165–185.

Cogswell, S. L. 1962. Tagging. In: Annual Report Biol. Lab., Woods Hole, Mass. for the year ending June 30, 1961. Circ. 137:70–74.

Dickerson, Charles L. 1939. Commercial fisheries. In: A Biological Survey of the Salt Waters of Long Island, 1938. Part I. N. Y. S. Cons. Dept.:15–46.

FINKELSTEIN, SAMUEL L. 1969a. Age and growth of scup in the waters of eastern Long Island. N. Y. Fish and Game Jour. 16(1):84–110.

_____ 1969b. Age at maturity of scup from New York waters. N. Y. Fish and Game Jour. 16(2):224–237.

GOODE, GEORGE B. 1884. The food fishes of the United States. In: The Fisheries and Fishery Industries of the U. S. Part III:163–682. U. S. Comm. Fish and Fisheries.

NESBIT, ROBERT A., AND WILLIAM C. NEVILLE. 1935. Conditions affecting the southern winter trawl fishery. U. S. Dept. Comm., Bur. of Fish. Fish. Circ. 18.

NEVILLE, WILLIAM C., AND GERALD B. TALBOT. 1964. The fishery for scup with special reference to fluctuation in yield and their causes. U. S. Fish and Wildl. Serv., Spec. Sci. Rep. Fish. 459.

PERLMUTTER, ALFRED. 1960. New York Federal Aid Project F-15-R (completion report for Job 7) N. Y. S. Cons. Dept. (mimeo.)

RICKER, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada, Bull. 119.

SMITH, W. G., AND JOHN J. NORCROSS. 1968. The status of the scup (*Stenotomus chrysops*) in the winter trawl fishery. Chesa. Sci. 9(4):207–216.

SCUBA OBSERVATIONS OF SPAWNING SMALLMOUTH BASS[1]

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ABSTRACT

SCUBA observations of naturally spawning smallmouth bass are described, and the behavior of the bass is compared with that reported by others. The principal difference concerned false spawning periods.

In June 1970, while working in Wilson Bay in eastern Lake Ontario, divers from the Cape Vincent Fisheries Station observed the entire spawning process of smallmouth bass (*Micropterus dolomieui*). Several differences in spawning activity from that previously recorded in the literature were noted. This paper describes these SCUBA observations of naturally spawning smallmouth bass and compares them with previous observations.

The spawning behavior of smallmouth bass has been described by several authors including Reighard (1905), Beeman (1924) and James (1930). These descriptions were primarily used by Adams and Hankinson (1928), Breder (1936) and Breder and Rosen (1966) in their summaries of the reproductive behavior of bass. Both Reighard and Beeman observed the bass from the banks of hatchery ponds. In contrast, James made his observations on bass in an aquarium.

METHODS

Three SCUBA divers doing routine checks on experimental smallmouth bass nesting boxes (2 feet square and filled with gravel) in Wilson Bay noted behavior related to spawning. The divers observed the spawning act of two smallmouth bass in 8 feet of water at a temperature of 64° F.

After first sighting the bass 6 feet away, the divers remained motionless on the bottom. Then, being careful not to make any sudden movements, the divers slowly swam forward until the faceplate of one diver's mask rested on the corner of the nest box, 6 inches from the spawning bass. Throughout the observations, the two bass showed no sign of being disturbed by the divers.

Other than for a 3-minute period at the beginning, the divers left the nest only to obtain fills of air. Throughout the entire process there was at least one diver present at the nest. Immediately afterward, each diver made separate notes on what he had seen. Since no watch or

[1] The author wishes to thank Kenneth W. Knopf and Ronnie J. Kernehan, the other two divers who made the observations. Thanks are also due Gerard C. Le Tendre, Dr. Richard C. Noble and William A. Pearce for reviewing the manuscript.

measuring device was available during the observations, special attempts were made to obtain accurate estimates of times and distances for various phases of the spawning behavior. Each diver made estimates separately. Then the three estimates were compared. The only figures quoted are those that were in close agreement.

RESULTS AND DISCUSSION

Due to the sequence of observed behavior, spawning activity was arbitrarily divided into four periods: prespawning, first false spawning, spawning and second false spawning. The total spawning process was judged to take 1½ hours to complete. Reighard (1905) noted that the entire process took 2 hours and 20 minutes, and James (1930) stated it took 2 hours.

PRESPAWNING PERIOD

The first check of the nest box revealed two bass moving in a series of circles over the nest. The circles were 4 to 5 feet in diameter, and the circling bass passed 4 to 12 inches over the box.

The circling continued for 5 minutes until the female failed to return from one of the circles. The divers then moved from their position 6 feet away to a point directly over the nest for close examination. No eggs were present and the male bass remained directly over the nest in front of the divers throughout the inspection.

The divers then left the area and returned after 3 minutes to find that the two bass were again circling. The circles were again 4 or 5 feet in diameter but gradually decreased until they were about 3 feet. These circles took 5 to 15 seconds to complete and with very few exceptions were clockwise when viewed from above. The position of the female during the circling was primarily a head-down, tail-up orientation at an approximate 25° angle. In contrast Reighard (1905) stated that the female swims slowly on her side most of the time, frequently floating motionless, partly or wholly turned on her side. James (1930), however, observed that the female's position between spawnings was virtually normal.

The body orientations of the male smallmouth bass during the spawning process can be best described as normal. He maintained a vertical position and swam normally. Reighard (1905) and Adams and Hankinson (1928) reported that during the circling period the male constantly hit the female, though gently, on the opercle, cheek and corner of the mouth. However, the male observed here was constantly nudging and nipping the female in the area from the pelvics to the vent, below the lateral line. He positioned the female between himself and the nest and appeared to use his nudging and nipping as a method to turn the female toward the nest. It was apparently very rare that the female would turn of her own accord.

During the period of circling over the nest the female would occasionally press the ventral portion of her body against some of the stones in the nest. Then she would dart up and away (12 inches) from the nest with accentuated lateral movements, flaring of the gill covers and opening of the mouth. Reighard (1905) observed this type of behavior in the female and interpreted it as a stimulus for the emission of eggs.

Observations on the coloring of the two fish coincided closely with those of other investigators. Both fish were darkly mottled, the female having a lighter background than the male. The male also had a distinctive red eye coloration that the female lacked.

First False Spawning Period

This spawning period was typified by a continuation of the circling, nudging and body orientations of the prespawning period. The female ceased her vent rubbing; this was also noted by Reighard (1905).

Occasionally on one of the circles, the two fish aligned themselves side by side over the nest. The female continued to remain in a head-down, tail-up orientation. The male remained quiet and upright as the female moved partially on her side with her head somewhat away from the male. At this time the female began a quivering, convulsive-like behavior that lasted approximately 4 seconds. During the quivering, the female's vent moved up and along the side of the male toward his dorsal fin as she turned partially on her side, bent slightly in an

Spawning smallmouth bass on an experimental nest box. The female has completed her convulsive-like behavior and is in an elevated position at the side of the male. This position is typical for the pair during the spawning and false spawning periods.

arc. When the quivering ceased, the two fish began moving in a slow circle again. James (1930) likewise observed that the female started her vibrations in a normal position and that at the conclusion she was generally turned partly on her side with the body bent in a slight arc. Reighard (1905) reported that the pair were side by side with the female lying partly on her side so that her median plane formed an angle of 45° with the plane of the horizon. Beeman (1924) related that the pair lay side by side with the female starting convulsivelike movements turning partially on her side.

This behavior continued for approximately 15 minutes; no eggs or milt were deposited on the nest, hence the terminology "first false spawning period."

Spawning Period

The behavior of the pair was identical to that during the first false spawning period except that eggs were now deposited on the nest. This period of egg deposition lasted approximately 45 minutes. The actual spawning occurred on every third or fifth circle. The first emission of eggs was comparatively small, less than 10. Shortly thereafter, the female began discharging approximately 30 to 50 eggs at a time. This figure agrees closely with observations of James (1930). He reported that 20 to 50 eggs were deposited at each spawning.

Reighard (1905) timed four discharges of eggs to be 4.0, 4.5, 5.5 and 6.0 seconds. He also timed five intervals between spawnings to be 22, 28, 30, 32 and 45 seconds. In contrast, James (1930) reported that discharge times were 10 seconds and that the interval between these spawnings lasted 3 minutes. The female observed here took approximately 4 seconds to spawn with 30-second intervals. These times closely agree with the findings of Reighard (1905).

The male during this period remained in a normal position and did not show signs of the stiffening and vibratory movement that James (1930) noted. The milt was discharged in a thin whitish thread an inch or more in length. At this time, its structure broke down and the milt dissipated as James (1930) noted.

At no time did the divers observe the male moving back after egg deposition to inspect the eggs as Reighard (1905) suggested. There was also no nipping of the female's vent or pectorals by the male after the female's discharge of eggs.

Occasionally during egg laying, the male would suddenly rush away from the nest, out of sight, and return in 5 to 10 seconds. The divers observed the male pursuing other fish at these times. While the male chased intruders, the female slowly moved away. The male would come back to the nest, rush off again, find the same female and bring her back. They would then resume spawning activity.

Second False Spawning Period

The egg deposition period was followed by another 15-minute period of false spawning. The female ceased laying eggs but the pair continued their spawning behavior. This period was also typified by the female straying into deeper water and then being brought back by the male for more spawning activity. Beeman (1924) and Reighard (1905) both suggested that once the female finishes depositing eggs, the male loses interest and drives the female away. The male observed here did not drive the female away. The female, on the contrary, moved away of her own accord and the male was left over the nest guarding the freshly deposited eggs.

CONCLUSION

The differences noted between the present observations and those of previous authors are likely ascribed to the variability of individual bass behavior and observational techniques. The principle difference concerned the false spawning periods. Possibly Reighard (1905) and Beeman (1924), because they were situated on a pond bank, did not see eggs emitted from the female at each discharge. James (1930) observed bass in an aquarium but did not note behavior associated with false spawning. In comparing his observations with those of Reighard (1905), he stated that "the presence of an excess number of males in the aquarium tank would very likely introduce modifications in the behavior of the fish which would fully account for the slight divergencies in the two observations." This might also explain why he did not observe any behavior associated with false spawning.

It must also be pointed out that the behavior observed as false spawning may have represented individual variation on the part of the pair studied rather than normal behavior of spawning bass.

LITERATURE CITED

Adams, C. C., and T. L. Hankinson. 1928. The ecology and economics of Oneida Lake fish. Roos. Wildl. Annual. Roos. Wildl. Forest Exper. Stat. Vol. 1:241–548.

Beeman, H. W. 1924. Habits and propagation of the small-mouthed bass. Trans. Am. Fish. Soc. 54:92–107.

Breder, C. M., Jr. 1936. The reproductive habits of the North American sunfishes (Family Centrachidae). Zoologica 21(1):1–47.

Breder, C. M., Jr., and D. E. Rosen. 1966. Modes of Reproduction in Fishes. Natural History Press, Garden City, N.Y.

James, M. C. 1930. Spawning reactions of small-mouthed bass. Trans. Am. Fish. Soc. 60:62–63.

Reighard, J. E. 1905. The breeding habits, development and propagation of the black bass (*Micropterus dolomieui*) and (*Micropterus salmonides*). Mich. Fish Comm., Bull. 7.

DIRECT MEASUREMENT OF POTASSIUM PERMANGANATE DEMAND AND RESIDUAL POTASSIUM PERMANGANATE

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ABSTRACT

In natural waters treated with potassium permanganate, residual potassium permanganate and potassium permanganate demand may be measured colorimetrically after appropriate dilution and treatment with orthotolidine. Procedures and formulas are given for determinations made with a spectrophotometer-colorimeter and for field determinations made with a color comparator.

Potassium permanganate ($KMnO_4$) is used in stream reclamation work to detoxify rotenone and antimycin. It is a strong oxidizing agent and, as such, is readily reduced by many naturally occurring organic compounds. In streams containing appreciable suspended organic matter, either as silt-sized particles or as colloidal humic materials, a measurable portion of introduced potassium permanganate is "used up" by reduction to tetravalent manganese compounds, the more usual ones being hydrates and complexes of manganese dioxide (MnO_2). Tetravalent manganese is ineffective against piscicides and is non-toxic to fish at low concentrations.

Controlled detoxification of piscicides with potassium permanganate requires accurate determination of the potassium permanganate demand, i.e., the amount of potassium permanganate reduced by naturally occurring materials during the detoxification period. Since equal concentrations of potassium permanganate and chlorine have very nearly the same oxidizing capacity, and since there are established methods for measuring the chlorine demand of natural water, it has been usual to use chlorine demand as an approximation of potassium permanganate demand for stream and pond reclamation purposes (Jackson, 1957; Loeb and Engstrom-Heg, 1970).

Since chlorine and potassium permanganate could not be expected to react with all reducing agents in the same manner and at the same rate, it would be advantageous to be able to measure potassium permanganate demand directly. Manganese, in both the Mn^{+7} and Mn^{+4} oxidation states, reacts with orthotolidine to produce the same yellow color used in residual chlorine determinations. Treatment of a dilute potassium permanganate solution with an excess of orthotolidine gives a color equivalent to that obtained with a chlorine solution of 91.7 per cent the concentration. If the same solution is reduced to the Mn^{+4} state, the color is equivalent to that obained with a chlorine solution of 38.5 per cent the concentration or an unreduced potassium permanganate solution of 42.7 per cent the concentration (based on data in

American Public Health Association et al., 1965). It should, therefore, be possible to determine concentrations of residual unreduced potassium permanganate colorimetrically. The situation is, however, somewhat more complicated than in the determination of residual chlorine, since reduction to Mn^{+4} does not cause complete fading of the color.

Tests conducted at the Fish Laboratory at Livingston Manor (N. Y.) were designed to develop a practical method of measuring potassium permanganate demand, first with a Spectronic 20 colorimeter-spectrophotometer, then with a simple color comparator for field determinations.

It was first determined experimentally that water solutions of potassium permanganate treated with orthotolidine conform closely to Beer's law within the 0.2 to 1.4 ppm range, the regression line for absorbance at 432 mμ being $A = 0.825C + 0.004$, where A is absorbance and C is concentration in ppm. The relationship between the colors produced by Mn^{+7} and Mn^{+4} was treated as follows:

Ao = absorbance of original potassium permanganate solution
A = absorbance of partly reduced sample
P = proportion of unreduced potassium permanganate remaining
Co = original potassium permanganate concentration in ppm
R = residual potassium permanganate concentration in ppm
D = potassium permanganate demand in ppm

and given that when $A = Ao$, $P = 1.0$
and that when $A = 0.427Ao$, $P = 0$
then these equations follow

(1) $P = \dfrac{A - 0.427Ao}{Ao - 0.427Ao}$

(2) $P = \dfrac{A - 0.427Ao}{0.573Ao}$

(3) $R = CoP$

(4) $R = Co\left(\dfrac{A - 0.427Ao}{0.573Ao}\right)$

(5) $D = Co - R$

(6) $D = Co - \dfrac{CoA - Co(0.427Ao)}{0.573Ao}$

(7) $D = \dfrac{Co(0.573Ao) - [CoA - Co(0.427Ao)]}{.573\ Ao}$

(8) $D = \dfrac{Co(Ao - A)}{0.573\ Ao}$

Various natural waters were treated with known concentrations of potassium permanganate and the absorbance at 432 mμ was measured after orthotolidine treatment at various time intervals. This experimentation led to the development of the following standard procedure for determining potassium permanganate demand with the Spectronic 20 or any similar instrument.

A. Reagents:
   1. Stock potassium permanganate solution. Dissolve 5.0 grams of potassium permanganate in distilled water, and make up to value of 500 milliliters.
   2. Orthotolidine solution, 0.1 per cent in hydrochloric acid (15 per cent by volume). This is the reagent used in chlorine determinations. It is sold in prepared form at most drug-stores.
   3. Distilled water.

B. Standardization:
   1. Pipet 0.6 milliliter of the stock solution to a 1,000-milliliter volumetric flask. Add distilled water to make 1,000 milliliters of a 6 ppm solution.
   2. Add 0.5 milliliter of orthotolidine to 90 milliliters of distilled water in a beaker.
   3. Add a 10-milliliter aliquot of the 6 ppm solution to the beaker.
   4. Determine the absorbance at 432 mμ of the resulting 0.6 ppm solution.

C. Potassium permanganate demand determination.
   1. Collect a 10-liter sample of the water to be tested. Stabilize the temperature at a value near that of the source body of water. If the water contains coarse suspended material, it should be kept in motion with an electric stirrer.
   2. Prepare a series of beakers, each containing 90 milliliters of distilled water and 0.5 milliliter of orthotolidine.
   3. Add 6 milliliters of the stock potassium permanganate solution to the water sample to obtain a 6 ppm solution. Stir well.
   4. At desired time intervals, transfer 10-milliliter aliquots of the treated sample to the beakers, mix well and determine the absorbance at 432 mμ.
   5. Compute potassium permanganate demand for each time interval. When the original concentration is 6.0 ppm. and the original absorbance of the diluted sample is 0.50, equation (8) becomes

$$D = \frac{6(0.50 - A)}{0.573(0.5)}$$

or (9) $D = 20.9(0.50 - A)$

D. Interpretation:

The potassium permanganate demand may be plotted against time to obtain a demand curve. Certain points on the curve may be of particular interest. For instance, if a stream is to be treated with the objective of detoxifying rotenone after 20 min-

utes of potassium permanganate-rotenone contact time, the 20-minute determination would be the crucial one or perhaps even the only one taken.

An initial value of 6.0 ppm was chosen because it is within the range used in stream work and because, at a 9:1 dilution (0.6 ppm), absorbance readings and computations are easy and reliable (absorbances range from 0.50 for unreduced potassium permanganate to 0.21 for Mn^{+4}). Demand curves based on this initial value will suffice for most situations. However, the demand does vary somewhat with the original concentration and, if the residual concentration at the end of the desired time is much less than that needed to detoxify the piscicide, it is recommended that additional tests be made with higher initial potassium permanganate concentrations.

Potassium permanganate demands and residual concentrations may be determined in the field with fair precision, using a color comparator calibrated for residual chlorine readings in the 0.1 to 1.0 ppm range. Since the color-concentration relationships for orthotolidine-treated potassium permanganate and chlorine are proportional, residual chlorine readings may be substituted for absorbances in equations (4) and (8). The method yields reasonable estimates of potassium permanganate demand in the absence of better instrumentation, and it is particularly valuable as a field check on residual concentrations at various points along a stream during treatment. The procedure is as follows:

A. Reagents: As in preceding procedure.

B. Standardization: Essentially as in preceding procedure. A 1.1 ppm potassium permanganate solution should read 1.0 ppm on the comparator scale.

C. Potassium permanganate demand determination:

1. Collect and prepare a 10-liter water sample as in preceding procedure.
2. Add stock potassium permanganate solution to obtain a known initial concentration.
   a. For clear water, add 1.1 milliliters of the stock solution to the 10-liter sample, for 1.1 ppm.
   b. For slightly turbid or stained water, add 5.5 milliliters of the stock solution to the 10-liter sample, for 5.5 ppm.
   c. For water carrying a heavy organic load, add 11.0 ppm of the stock solution to the 10-liter sample, for 11 ppm.
3. At desired time or times, place an aliquot of solution in a 100-milliliter or larger beaker and add 0.5 milliliter of orthotolidine.
   a. For 1.1 ppm, use 100-milliliter aliquot and do not dilute.

b. For 5.5 ppm, use 20-milliliter aliquot and dilute with 80 milliliters of distilled water.

c. For 11.0 ppm, use 10-milliliter aliquot and dilute with 90 milliliters of distilled water.

If work is done outdoors, it should be done in a shaded location. The yellow color fades rapidly in direct sunlight.

4. Place sample from beaker in comparator and read residual chlorine value. Compute potassium permanganate demand according to equation (8), using $Ao = 1.0$ and A = residual chlorine reading at end of time period. Table 1 gives some representative values.

TABLE 1. APPROXIMATE MEASUREMENT OF POTASSIUM PERMANGANATE DEMAND WITH A CHLORINE COMPARATOR

Residual chlorine reading (ppm)	Potassium permanganate					
	1.1 ppm no dilution		5.5 ppm 20–80 dilution		1.1 ppm 10–90 dilution	
	Residual	Demand	Residual	Demand	Residual	Demand
1.0	1.1	0.0	5.5	0.0	11.0	0.0
0.9	0.9	0.2	4.5	1.0	9.0	2.0
0.8	0.7	0.4	3.5	2.0	7.0	4.0
0.7	0.5	0.6	2.5	3.0	5.0	6.0
0.6	0.3	0.8	1.5	4.0	3.0	8.0
0.5	0.1	1.0	0.5	5.0	1.0	10.0
0.4	0.0	1.1	0.0	5.5	0.0	11.0

D. Field determination of residual potassium permanganate. This assumes the chemical to have been introduced continuously into a stream at a known rate, to give a known initial concentration. It is also assumed that enough time has elapsed for the concentration to build up to a stable plateau value at the sampling point and that any dilution from springs or tributaries has been taken into account.

1. Collect a 20-milliliter sample from the stream at a desired point.
2. Dilute to 100 milliliters with distilled water.
3. In a shaded location, add 0.5 milliliter of orthotolidine to the sample.
4. Place an aliquot of the sample in the color comparator and read the residual chlorine value.
5. Compute the residual potassium permanganate from equation (4) or equations (5) and (8).

Co = initial potassium permanganate concentration, corrected for natural dilution.

Ao = residual chlorine reading corresponding to 0.2 Co. This may be determined in the laboratory before field tests are run.

A = residual chlorine value of the sample.

It is important that the addition of orthotolidine to the sample be done in a shaded location.

LITERATURE CITED

Jackson, C. F. 1957. Detoxification of rotenone-treated water. N.H. Fish and Game Dept., Tech. Circular 14.

Loeb, Howard A., and Robert Engstrom-Heg. 1970. Determination of chlorine demand. N.Y. Fish and Game Jour. 17(2):138–139.

American Public Health Association et al. 1965. Standard Methods for the Examination of Water and Wastewater, New York, 12th ed. Am. Public Health Assoc. Inc.

TRANSPORTING AND HANDLING YOUNG AMERICAN SHAD[1]

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ABSTRACT

Procedures for successfully transporting and handling young American shad are described. Mortality frequently encountered in handling this species is attributed primarily to stress arising from excitement.

Transportation and handling of young American shad (*Alosa sapidissima*) has long been considered a difficult problem. Leach (1925) stated that fingerling shad are so tender that the numbers released each year could not be determined, because the fish could not withstand the handling associated with counting, not even tolerating transfer in dippers of water. The only account of a system used successfully to transport young shad is that of Sykes (1950) which was based on but two successful attempts at transporting these fish. The present account is based upon much more experience than Sykes reported on and presents an explanation for difficulties encountered in handling this species.

INITIAL EQUIPMENT AND TRIALS

American shad were seined from freshwater sections of the Delaware River and transported to Rutgers University at New Brunswick, N.J. A wooden tank of the following inside dimensions was used to transport the fish: length and width, 40.5 inches; depth, 20.5 inches; capacity, 145 gallons. Only about 100 gallons of water were used, because the excess would spill out during travel. Water turbulence was reduced by a vertically emplaced board which extended 6 to 15 inches from the bottom of the tank. The vehicle containing the tank was driven as close as possible to the shoreline before seining was begun. The net was drawn to shore in such a manner that a pocket remained in which the shad could swim freely yet be readily captured. A scoop (Figure 1) fashioned from a half-gallon plastic Clorox bottle was used to capture one or a few fish at a time, and they were immediately transferred into a 2.5-gallon pail placed next to the net or directly into the tank. The fish were allowed to swim from the scoop or were gently poured out. The return trip began after the equipment was reloaded. Upon arrival, most of the water was siphoned from the tank. Then the

[1] Derived from a Ph.D. thesis submitted to Rutgers University, New Brunswick, New Jersey. The study was supported, in part, by the Sport Fishing Institute and by training grants from the U.S. Public Health Service.

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Figure 1. Scoop used for transferring American shad.

shad were scooped out, placed in a bucket and transferred about 15 feet to a large aquarium. The fish ranged in size from about 2 to 3.5 inches in total length.

On August 28, 1964, about 50 shad were transported. Nine fish died during the 2.5-hour trip, and 31 more died in the next few days. The shad were roughly handled during removal from the tank, and the dead fish showed signs of hemorrhaging. At the time, it was felt that the system might be successful if the fish were handled more gently.

On July 15, 1965, 42 fish were transported, but only seven survived the 4-hour trip.

On July 21, 1965, about 50 shad were transported, and about 25 died during the 4-hour trip. Many of the dead fish had lost scales. While the vehicle was being driven from the bank of the river to the highway, the water in the tank became so turbulent that some fish were thrown out.

Because of these poor results, it was decided to modify the tank and the procedures used.

MODIFICATION OF THE TRANSPORTATION TANK AND PROCEDURES

Provision was made for a removable false top ½ inch above the vertical baffle. A 2 × 3-inch board fitted at its lower edge with a 1 × 1-inch shelf was attached to each of two opposite walls of the tank. The

shelves supported the false top which consisted of four 1-inch-thick boards that fitted tightly together when in place. A brass handle on one board facilitated placement and removal. Then 1 × 6-inch boards were fitted tightly over the ends of the false top and were held firmly in place by wing nuts on threaded rods passing through these boards and the 2 × 3-inch boards. The top of the tank had a 3-inch in-facing rim, and two threaded rods were installed through this rim at each corner to hold a plywood top. Thus, the tank had essentially two compartments, the lower of which held the fish and about 100 gallons of water. Tolerances of construction were such that the parts could be assembled and disassembled with minimal disturbance to the fish. The arrangement is shown in Figure 2.

Laboratory experience indicated that young shad would survive a direct transfer from fresh water to salt water having a salinity of 29 ppt and would thrive in this medium. Sykes (1950) successfully used brackish water to transport these fish on two occasions. As a result, it was decided to transport shad in brackish water (salinity about 5 ppt). Sufficient seawater was added to the transportation tank to give this salinity when it was completely filled. Tap water was then added to fill the tank to the false top, and the filled tank was transported to the river. The vehicle was parked so that there would be no surging of water in the tank on leaving the river.

A light was used to attract large numbers of shad to the shoreline where they could be seined at night. The scoop and the transfer pro-

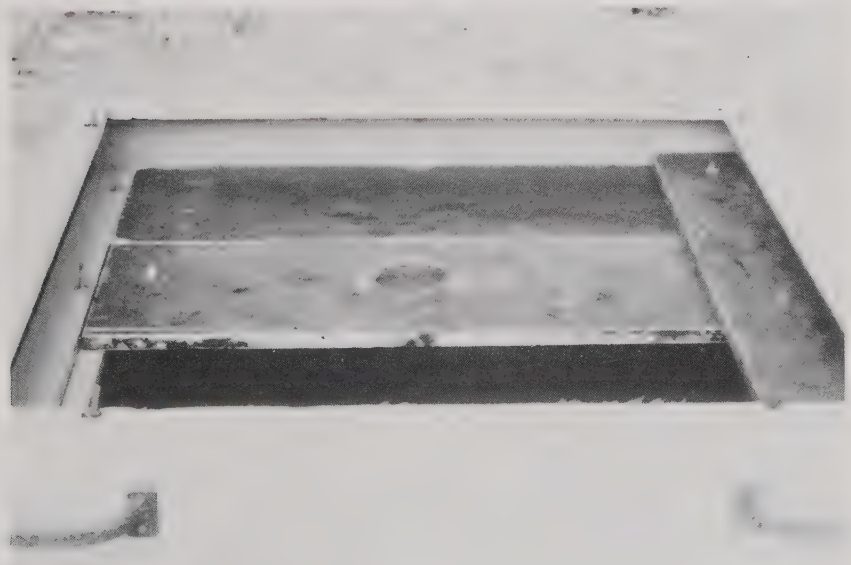

Figure 2. The successful transportation tank.

cedure were also modified. The initial scoop had a narrow neck into which the shad would frequently swim and from which it was difficult to remove them. The neck was filled with paraffin to avoid this problem. Fish were scooped up and immediately transferred to a washtub or a pail located next to the net. On the first night a pail was used to transfer fish to the tank, but it was not satisfactory and a washtub was used thereafter. The shad did not seem excited in the washtub, an obvious problem with the smaller pail. About 50 fish were placed in the washtub before it was carried to the transportation tank. The washtub was immersed in the tank to allow the shad to escape. After sufficient fish were obtained, water was siphoned to the level of the false top and this was installed. The tank was then completely filled with river water, and the plywood top was installed.

An air pump was used during several trips, but not on all occasions. The best roads possible were taken to avoid jarring, turbulence, etc. that might excite the shad. Both the plywood top and false top were removed upon arrival at the laboratory, and the fish were transferred inside immediately or the following morning. Aeration was usually provided if the fish were left in the tank overnight. A floating net was constructed to half the size of the transportation tank dimensions. This net was used to trap and confine the fish, so that they could readily be scooped. Shad were scooped from the transportation tank to a washtub and carried indoors to large holding tanks filled with water of 5 ppt salinity. This was eventually changed to fresh water by flushing.

RESULTS AND DISCUSSION

The modified system was used to transport young shad on 11 occasions. Table 1 summarizes the general conditions in each case and the results. As in the initial trials, there was little or no success when fish were transported in fresh water. Except on two occasions, essentially complete survival, over a temperature range of about 13° to 27° C., occurred when brackish water was used for transportation and for initially holding the fish in the laboratory. I believe a low dissolved oxygen level resulting from lack of overnight aeration was the problem on September 19, 1965 because the survivors were fine once in the laboratory. Mortality on September 15, 1965 was probably due to excitement of the fish caused by using a pail in transferring them. However, 85 of 100 fish survived – far better than with fresh water.

Sykes (1950) believed that shad remained more vigorous and were not so susceptible to mortality if brackish water was used in transportation. On the one occasion when he attempted to transport young shad in fresh water, they all died. Hollis (1948) tagged young shad successfully. It is significant that, after tagging, Hollis held the fish for

TABLE 1. SUMMARY OF DATA RELATING TO TRIALS OF MODIFIED PROCEDURE FOR TRANSPORTING SHAD

Date	Length of trip (hours)	Water type	Water temperature (°C.)	Number of fish	Mortality and comments
			1965		
September 15	1.5	Brackish	21–27	100	1 died during trip; 15 died in next few days; all dead fish had lost many scales.
September 20	1.5–2	Brackish	21–27	85	All survived trip; OK in laboratory.
September 21	1.5–2	Brackish	21–27	160	All survived trip; about 90 were dead next morning, and survivors were swimming at surface; survivors OK in laboratory.
September 22	1.5–2	Brackish	24–26	250	1 died, a fish that had been in distress; OK in laboratory.
			1966		
August 10	3	Fresh	24	95	Nearly all dead on arrival; survivors swimming at surface in distress.
August 21	3	Brackish	21–24	75	All survived trip; OK in laboratory.
September 9	1.5	Fresh	23–19	60	2 died during trip; 23 died in next few hours and others in distress; 26 died in next two days; fish not visibly injured.
September 20	2.5	Brackish	16–18	60	All survived trip in spite of rough handling; OK in laboratory.
September 21	1.5	Brackish	16	64	All survived trip in spite of rough handling; OK in laboratory.
September 25	1.5	Brackish	13–16	74	All survived trip in spite of rough handling; 1 had lost equilibrium in seine; OK in laboratory.
September 26	2	Brackish	14–17	44	All survived trip in spite of rough handling; OK in laboratory.

14 days or more in Ringer solution, which has a composition similar to that of brackish water. His initial attempts to mark young shad without using Ringer solution always resulted in death within a few days and, from his account, it appears these attempts involved fresh water. It seems evident that the use of brackish water as a transportation medium is one of the keys to successful transportation and handling of young shad.

The actual cause of the mortality frequently observed when handling or transporting shad may not be due to mechanical injury (Chittenden, 1969). Response of American shad to handling suggests an emergency response to a stressor stimulus, and the intensity of emotional excitement caused by handling seems to determine the fate of the fish. If mild, the response is mild and there is no mortality. If intense, there may be immediate mortality due to some presently unclear overreaction. If of intermediate intensity, adaptation to meet the emergency results in lactic acid accumulation and delayed mortality associated with acid-base disturbance and a Bohr effect. Brackish water as a transportation medium seems to minimize delayed mortality, but my experience in handling young shad suggests that salt water does not prevent an immediate mortality associated with intense stress. I believe the most important key to successful handling of shad is to minimize the excitement induced by handling. In general, all equipment and procedures were designed to cause minimal excitement. If suitable precautions are taken, I feel that transportation and handling of young shad is simple.

LITERATURE CITED

Chittenden, Mark E., Jr. 1969. Life history and ecology of the American shad, *Alosa sapidissima*, in the Delaware River. Ph.D. thesis, Rutgers Univ.

Hollis, E. H. 1948. The homing tendency of shad. Science. 108:332–333.

Leach, G. C. 1925. Artificial propagation of shad. Rep. U.S. Comm. Fish. (1924) App. 8, Bur. Fish. Doc. 981:459–486.

Sykes, J. E. 1950. A method of transporting fingerling shad. Prog. Fish-Cult. 12: 153–159.

ESTIMATION OF ROTENONE CONCENTRATION BY BIO-ASSAY

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ABSTRACT

Concentration-response curves were determined for brown trout placed in water dispersions of emulsifiable rotenone. The response measured was loss of equilibrium. The values obtained yielded linear plots on logarithmic paper, when estimated threshold values were subtracted from the concentrations and response times. Linear plots were also obtained by plotting reciprocals of response times against logarithms of concentrations, using semi-logarithmic paper. The intercept of the regression line with the log concentration axis is an estimate of the threshold concentration. The curves obtained have proved to be reliable indicators of residual rotenone concentrations, particularly within the 0.05 to 0.3 ppm concentration range.

Concentration of very dilute rotenone solutions is most easily determined by bio-assay. Chemical methods, such as those of Goodhue (1936) and Post (1955), are time-consuming, and because of the solvent-extraction techniques involved they do not always yield reliable results. An essential of the bio-assay method of determining concentration is a curve showing a relationship between the concentration and the time required to obtain a given response from an experimental animal under standard conditions. In work with fish toxicants, the response used is usually either loss of equilibrium or death. Burdick et al. (1955, 1956) worked out rotenone concentration-response curves for several species of freshwater fish, using death as the response. Cohen et al. (1960) established such a curve for the fathead minnow (*Pimephales promelas*), using loss of equilibrium as the response.

Extensive experiments were carried out at the Fish Laboratory at Livingston Manor (N.Y.) on the detoxification of rotenone with activated carbon and with potassium permanganate. The available experimental fish were young brown trout (*Salmo trutta*) of Catskill Hatchery stock. Proper evaluation of detoxification experiments required the determination of reliable concentration-response curves for these fish. The experiments described here were conducted to establish such curves.

METHODS

Previous tests had shown that for trout in rotenone preparations, time to loss of equilibrium was less variable and more easily measured than time to death. Loss of equilibrium was therefore used as the response in all tests. It was assumed that a fish had lost equilibrium when its mid-dorsal line first came in contact with the bottom of the container.

The experiments were conducted in 20-gallon rectangular glass aquaria containing laboratory spring water (pH, 6.8; total alkalinity, 14 ppm; total dissolved solids, 23 ppm) at constant temperatures of 47° and 65° F.

The trout used had a mean weight of 75 grams per fish. They had been acclimated for at least a week at the experimental temperatures and had not been fed during the 48-hour period prior to an experiment. Rotenone solutions were prepared by adding appropriate amounts of a 0.1 per cent stock dispersion of 5 per cent emulsifiable rotenone (Noxfish [1]) to the water in the aquaria. Solutions were allowed to stand for 4 hours to allow for complete solution of rotenone (Loeb and Engstrom-Heg, 1970). Eleven trout were added to each aquarium, and times to loss of equilibrium were recorded.

RESULTS

Times to loss of equilibrium were obtained for Noxfish concentrations ranging from 1.5 ppm to 0.05 ppm at 47° F. and from 1.5 ppm to 0.04 ppm at 65° F. Some fish survived at 0.04 ppm at 47° F. and at 0.03 ppm at 65° F. No fish lost equilibrium at 0.03 ppm at 47° F. or at 0.02 ppm at 65° F. (Tables 1 and 2). At 0.04 ppm (47° F.) and at 0.03 ppm (65° F.) there were instances of fish losing equilibrium and sub-

Table 1. Turn-over Time for Brown Trout in Noxfish Dispersions at 47° F.

Noxfish concentration (ppm)	Turn-over time (minutes)			
	Experimental mean	Standard deviation	Values from regression equations	
			Logarithmic	Semilogarithmic
1.50	15.8	0.94	17.6	16.7
1.00	19.5	1.37	19.8	18.9
0.75	21.5	2.06	21.8	20.8
0.50	26.6	1.72	25.4	24.3
0.30	34.7	1.35	32.0	30.9
0.10	73.4	7.97	67.8	74.0
0.08	100.7	21.00	89.3	99.2
0.05	187.0	39.20	295.0	563.0
0.04	*	..	∞	∞
0.03	§	..	∞	∞
0.02	§	..	∞	∞

* Incomplete turn-over.
§ No turn-over.

sequently recovering. When response time was plotted against concentration on linear graph paper, the result was a curve, for each temperature, having the general characteristics of a hyperbola. A plot on logarithmic paper yielded a pair of hollow curves. Straight lines were obtained by applying the method of Burdick (1957). It was found

[1] S. B. Penick & Company, Jersey City, New Jersey.

TABLE 2. TURN-OVER TIME FOR BROWN TROUT IN NOXFISH DISPERSIONS AT 65° F.

Noxfish concentration (ppm)	Turn-over time (minutes)			
	Experimental mean	Standard deviation	Values from regression equations	
			Logarithmic	Semilogarithmic
1.50	8.2	0.76	8.8	8.6
1.00	9.9	0.90	9.6	9.6
0.75	10.2	1.03	10.3	10.5
0.50	11.7	1.65	11.7	12.0
0.30	13.8	1.20	14.1	14.6
0.10	28.0	1.22	26.1	28.0
0.08	32.1	2.57	31.3	34.4
0.05	56.9	2.78	53.8	66.5
0.04	91.7	18.2	83.4	118.1
0.03	*	..	∞	∞
0.02	§	..	∞	∞

* Incomplete turn-over.
§ No turn-over.

that straight lines could also be obtained on semi-logarithmic paper by plotting the logarithm of the concentration against the reciprocal of the response time. Regression equations
in which

C = Noxfish concentration in ppm
T = response time in minutes

were as follows:

A. Logarithmic plots:
1. At 47° F.: $\log (T - 11) = -0.6617 \log (C - 0.045) + 2.254.$
2. At 65° F.: $\log (T - 6.5) = -0.7015 \log (C - 0.03) + 1.886.$

B. Semi-logarithmic plots:

1. At 47° F.: $\log 100C = \dfrac{25.53}{T} + 0.6562$

or $\qquad T = \dfrac{25.53}{\log C/0.045}$

2. At 65° F.: $\log 100C = \dfrac{14.634}{T} + 0.4771$

or $\qquad T = \dfrac{14.634}{\log C/0.03}$

The logarithmic and semi-logarithmic equations are not mathematically identical, but they do yield practically identical solutions for the concentration-response relationship over the full range of experimental values, except for values very near the threshold concentration. For these points, the logarithmic values correspond more closely with the data (Tables 1 and 2, Figure 1).

DISCUSSION

Many workers have attempted to plot logarithms of concentration

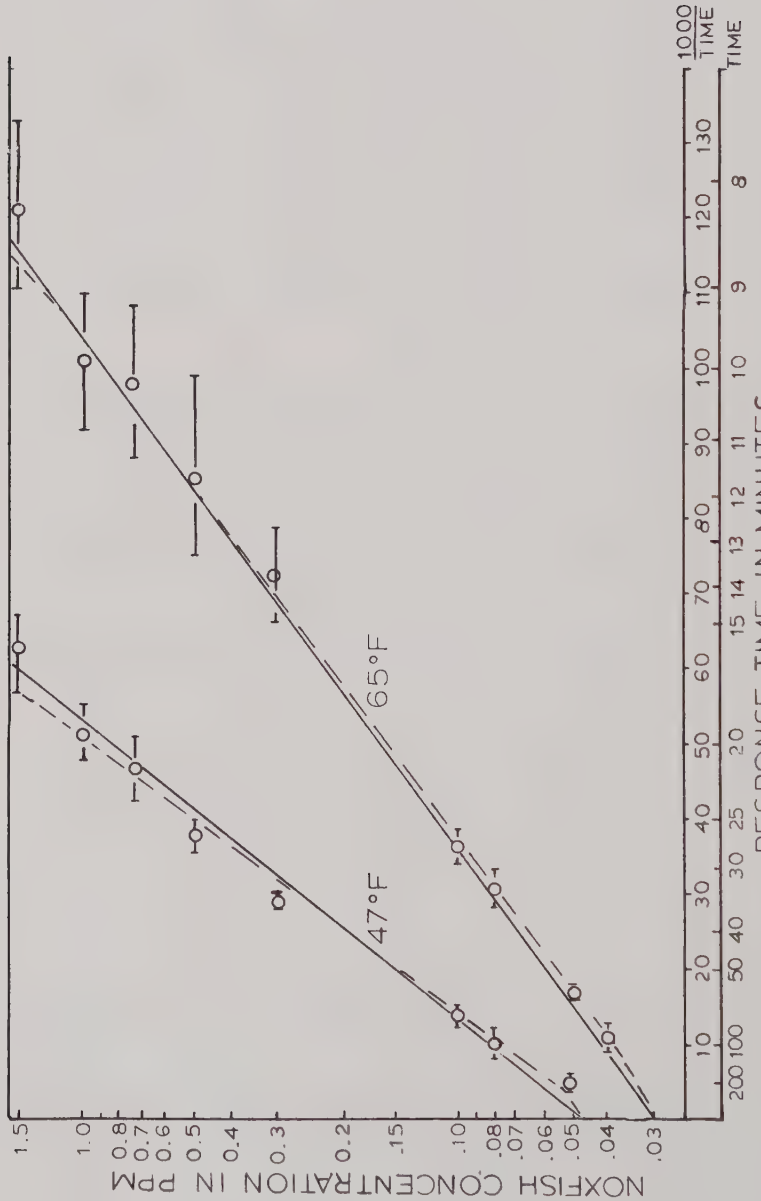

Figure 1. Concentration-response curves for brown trout in Noxfish dispersions. Solid lines represent semilogarithmic, dashed lines logarithmic, regressions. Each point represents mean time to loss of equilibrium ± standard deviation.

against logarithms of response time. The resulting curve is linear if there is a simple inverse proportion between concentration and time, since in such a case the product of concentration and time would be a constant, i.e., $CT = k$, and $\log C + \log T = \log k$. In real situations, such a relationship may be approximately valid, at least for certain sets of values. Sometimes, however, the plot on logarithmic paper departs rather markedly from linearity. Burdick (1957) showed that a non-linear plot could be made linear by assuming that the response did not occur below a certain threshold concentration a and that a certain minimum time b was required for the response to occur, even at high concentrations. If this were true, $(C - a)(T - b) = k$ and $\log (C - a) + \log (T - b) = \log k$. Direct application of this formula did not give reliable results. However, it was found that a linear relationship could be approximated by plotting $(C - a)$ against $(T - b)$ on logarithmic paper, using those trial values of a and b that gave the most nearly linear results. Application of the standard regression formulas yields an equation of the form $\log (T - b) = b' \log (C - a) + a'$, where a' and b' are the regression constants.

Substitution of the semi-logarithmic relationship, $T = \dfrac{k}{\log c/a}$ for the logarithmic relationship could have certain advantages if it could be shown to be generally applicable to concentration-response relationships. The intercept of the regression line with the log concentration axis is an estimate of the threshold concentration a (concentration corresponding to an infinite response time). Thus, some of the trial-and-error aspects of Burdick's method might be eliminated, and it might be possible to obtain reliable estimates of bio-assay parameters for given chemicals and fish species with greater ease and, perhaps, with fewer experiments.

The concentration-response curves have been used extensively over the past two years to estimate residual rotenone concentrations from bio-assay data. Periodic checks using Noxfish solutions of known concentration have all tended to confirm the validity of the curves for brown trout from the Catskill Hatchery and their relatively high precision as indicators of Noxfish concentration, particularly within the 0.05 to 0.3 ppm range.

LITERATURE CITED

BURDICK, GEORGE E., HOWARD J. DEAN AND EARL J. HARRIS. 1955. Toxicity of emulsifiable rotenone to various species of fish. N. Y. Fish and Game Jour. 2(1):36–67.

_____ 1956. Toxicity of emulsifiable rotenone to yellow perch. N. Y. Fish and Game Jour. 3(1):75–79.

BURDICK, GEORGE E. 1957. A graphical method for deriving threshold values of toxicity and the equation of the toxicity curve. N. Y. Fish and Game Jour. 4(1): 102–108.

Cohen, Jesse M., L. J. Lamphake, A. E. Lemke, C. Henderson and R. L. Woodward. 1960. Effect of fish poisons on water supplies. Part 1, Removal of toxic materials. Jour. Am. Water Works Assn. 52(12):1551–1566.

Goodhue, Lyle D. 1936. An improvement on the Gross and Smith colorimetric method for the determination of rotenone and deguelin. Jour. Assn. Official Agr. Chem. 19:118–120.

Loeb, Howard A., and Robert Engstrom-Heg. 1970. Time-dependent changes in the toxicity of rotenone dispersions to trout. Toxicol. and Appl. Pharmacol. 17(3): 605–614.

Post, George. 1955. A simple color test for rotenone in water. Prog. Fish-Cult. 17(4):190–191.

RECOLONIZATION OF A ROTENONE-TREATED SEGMENT OF THE TEN MILE RIVER

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ABSTRACT

Recolonization of the upstream 500 feet of a 2,100-foot rotenone-treated section of the Ten Mile River was studied over a 10-month period. At the end of the period, the fish population and fish biomass were estimated as 69.2 and 32.1 per cent of their respective pretreatment values. Immigrant fish of most species tended to be smaller and younger than fish of the same species in the pretreatment population. A notable exception was the American eel, the species contributing most to the fish biomass.

On October 1, 1969, a 2,100-foot section of the Ten Mile River near Narrowsburg, New York, was treated with 5 per cent emulsifiable rotenone (Noxfish [1]) at a concentration of 1 ppm for a period of 6 hours. Prior to treatment, a temporary fish-tight barrier (Loeb et al., 1970) had been placed in the stream 500 feet downstream from the rotenone introduction site. On September 24-25, a portion of the native fish above the barrier had been captured by electrofishing and marked by fin clipping. In addition, on September 22, a marked lot of 650 fingerling brown trout was released in the area. Trout captured on September 24 were marked again by excising an additional fin. Resampling on September 25 indicated that less than 10 per cent of the released trout remained in the area, the majority apparently having migrated upstream, since the barrier prevented downstream migration, and no dead fish were observed.

The 500-foot treated segment above the barrier was predominantly shallow and rubble-bottomed, consisting of alternating riffles and shallow pools. Its area was estimated to be 0.56 acre in October 1969. On the treatment date, an intensive effort was made to recover all dead fish from this segment. Separate counts were made of fish that swam or drifted into the barrier. Peterson-type population estimates were made for each species, based on recovery of 20 to 78 per cent of the marked fish, depending on the species. Collected fish were preserved, weighed and measured. Stomach contents of some of the larger specimens were examined.

Recoveries at the barrier indicated some drift of ailing fish out of the sample segment, but little or no "herding" effect from any repellant action of the Noxfish was observed. Except for common shiners,

[1] A product of S. B. Penick Co., Jersey City, N.J.

most fish appeared to have died and settled to the bottom within a few feet of the point where they first encountered the toxicant. There was evidence that some distressed fish reacted by seeking cover under rocks in the streambed. Estimated proportions of dead fish remaining within the sample segment ranged from 100 per cent for the longnose dace, cutlips minnow and blackside darter to 75 per cent for the common shiner. Marked to unmarked ratios did not differ significantly between recoveries from the streambed and from the barrier. It was possible, then, to base population estimates entirely on recoveries from the streambed without introducing bias.

Examination of eel stomachs revealed that these fish had fed to some extent on brown trout, longnose dace and blacknose dace, probably during the treatment period, since eels were among the last fish to die. Six fish were found in 10 stomachs. All trout stomachs examined were empty, and fallfish stomachs contained only aquatic insect fragments. No fish-eating birds were observed near the stream. It seems unlikely that predation interfered seriously with recovery of dead fish.

The Ten Mile River was sampled by electrofishing on November 17-18, 1969, and again on June 18, 1970. Results in terms of catch per 100 feet are given in Table 1. Fish recovered in November in the

Table 1. Results of Electrofishing in a Segment of the Ten Mile River Before and After Rotenone Treatment

Date	Area	Distance sampled (feet)	Mean catch (fish per 100 feet)
September 24, 1969	Pretreatment	500	45.6
November 17–18, 1970	Treated	900	1.3
	Untreated	480	26.5
June 18, 1970	Treated	1,400	17.7
	Untreated	800	44.4

treated area were all small and probably represented immigration rather than survival. No fish were recovered from a 400-foot segment near the center of the treated area.

On August 4, 1970, the river was again treated with rotenone. No barrier was used, and there was no attempt to mark fish before the treatment, but fish were collected intensively from the streambed of the 500-foot segment that had been sampled the previous year. Population estimates were made, assuming that the percentage recovery of dead fish was the same as in the previous year. This assumption is reasonably well justified, since the samplings were made in a similar manner, and since on both occasions the stream was low and clear. Fish were weighed and measured as in 1969. Results are summarized in Table 2. Over a 10-month period, the treated area had been partly but not entirely recolonized by immigrant fish.

TABLE 2. FISH POPULATION ESTIMATES BASED ON FISH RECOVERIES AFTER 1969 AND 1970 ROTENONE TREATMENTS OF THE TEN MILE RIVER

Species	Estimated population		Mean weight per fish (grams)		Estimated biomass (pounds per acre)		Estimated percentage of total biomass		Estimated percentage repopulation *	
	1969	1970	1969	1970	1969	1970	1969	1970	Biomass	Number
Brown trout (*Salmo trutta*)	62 §	4 §	15.7	115.5	3.83	1.82	3.6	5.4	47.5	6.4
American eel (*Anguilla rostrata*)	116	29	99.2	95.5	45.30	10.84	42.8	31.9	23.9	25.0
White sucker (*Catastomus commersoni*)										
3 inches and under	0	325 †	..	2.0	0.00	2.54	0.0	7.5	100+	100+
over 3 inches	21	32	159.7	54.6	13.20	6.84	12.5	20.1	51.8	100+
Blacknose dace (*Rhinichthys atratulus*)	495	378	1.9	1.2	3.71	1.80	3.5	5.3	48.5	76.3
Longnose dace (*Rhinichthys cataractae*)	232	86	4.1	4.3	3.73	1.45	3.5	4.3	38.9	37.0
Common shiner (*Notropis cornuta*)	75	25	18.4	10.0	5.42	0.98	5.1	2.9	18.0	33.3
Fallfish (*Semotilus corporalis*)										
3 inches and under	117	94	1.9	1.5	0.87	0.55	0.8	1.6	63.2	80.3
over 3 inches	80	21	60.1	27.0	18.85	2.22	17.7	6.5	11.8	26.2
Cutlips minnow (*Exoglossum maxilingua*)	12	4	18.4	6.3	0.88	0.11	0.8	0.3	12.5	33.3
Eastern madtom (*Noturus insignis*)	46 †	16 †	12.0	10.5	2.16	0.66	2.1	2.0	30.2	34.7
Blackside darter (*Percina maculata*)	678	283	3.0	3.3	8.00	3.67	7.6	10.8	25.8	41.2
Smallmouth bass (*Micropterus dolomieui*)	0	43 †	..	2.9	0.00	0.50	0.0	1.4	100+	100+
Total	1,934	1,340	xxx	xxx	106.00	34.00	100.0	100.0	32.1	69.2

* Derived from 100 × 1970 value/1969 value.
§ Brown trout were probably all hatchery fish of 1968 year class.
† No fish marked; estimate based on assumed recovery of 50 per cent.

It should be noted that for most species the average size was smaller in 1970 than in 1969, indicating colonization by small immature individuals. Notable exceptions were American eel and longnose dace. For these species, the immigrant fish appeared to represent the same size mix found in the rest of the stream.

These findings tend to confirm the generally accepted view that stream reclamation is not likely to be a profitable undertaking in the absence of barriers to immigration. However, since the immigrants tended to be small, there is a possibility that recolonization by excessive numbers of non-game fish might be delayed by stocking a newly reclaimed segment with trout, bass or pickerel large enough to exert predatory pressure on the immigrating fish.

LITERATURE CITED

Loeb, Howard A., Robert Engstrom-Heg and Kenneth F. Stafford. 1970. A temporary barrier for shallow streams. N.Y. Fish and Game Jour. 17(2):135–137.

GENERAL NOTES

A DWARF, BRACHYCEPHALIC GRAY FOX[1]

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In February 1970, a gray fox (*Urocyon cineroargenteus*) was found injured along a highway in Yates County (N.Y.). The fox was killed and submitted to the Wildlife Research Laboratory at Delmar for examination because of its small size and unusual appearance.

At gross examination, the fox (Figure 1) was found to be a dwarf male with a protruding lower jaw (prognathism) which gave it a "bull dog" appearance. The

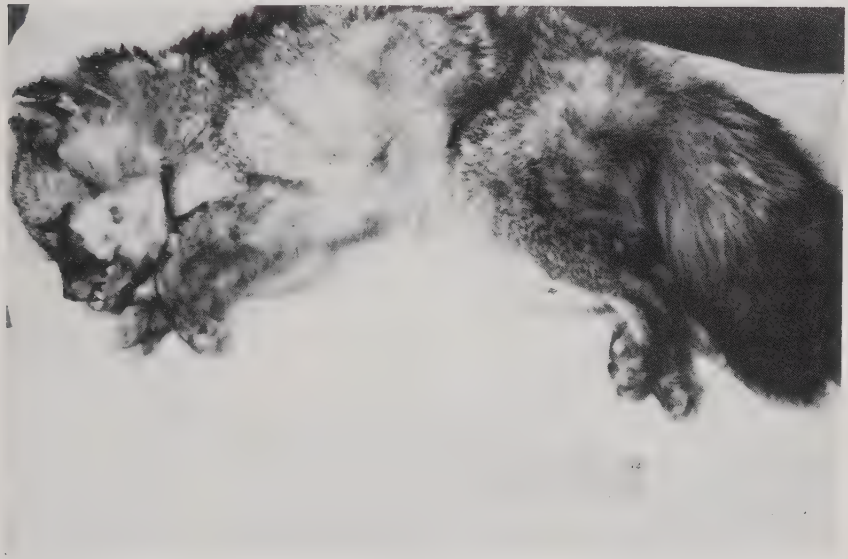

Figure 1. Dwarf gray fox from Yates County, New York.

fox weighed 4¼ pounds but was in good flesh. This was less than half the weight of gray foxes (9–12 pounds) autopsied at the Laboratory during the winter months. Wood (1958) reported a mean body weight of 9.1 pounds for 93 adult male gray foxes and 8.1 pounds for ten 9-month-old male gray foxes in Georgia.

External measurements, in millimeters, of this dwarf fox were: body length 393, hind foot 89 and tail 229. Blair et al. (1957) gave the following approximate corresponding measurements for the species: body length 530–740 and hind foot 120–

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-35-R and the New York State Wildlife Rabies Control Program. The authors wish to thank Nicholas Drahos for the skull photography.

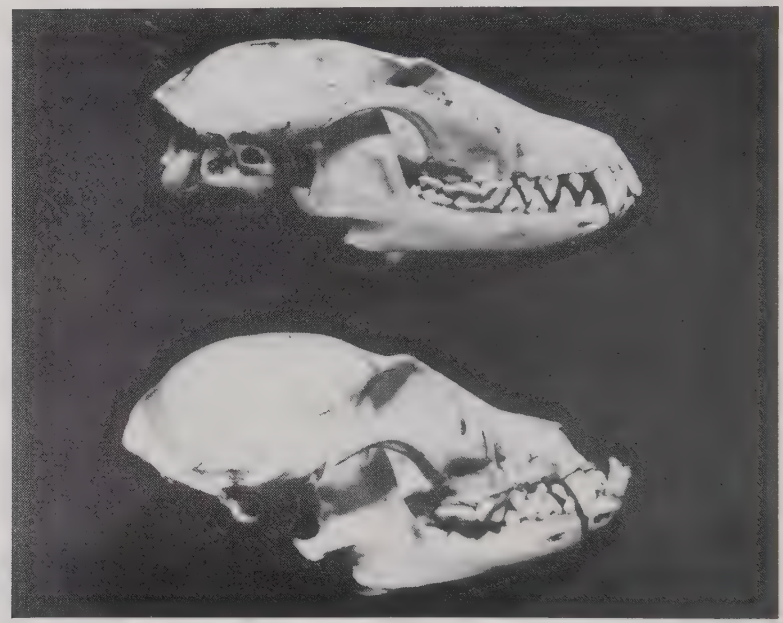

Figure 2. Lateral view of (above) skull of normal adult male gray fox and (below) skull of dwarf specimen.

Figure 3. Dorsal view of (left) skull of normal adult male gray fox and (right) skull of dwarf specimen.

150; and noted the tail as 50 to 55 per cent of the body length. Comparison shows that the body length and the hind foot length of the present specimen were approximately 74 per cent of the minimum measurements for normal adults. The dwarf fox's tail length of 58 per cent of the body length was about in the normal proportion.

At autopsy, no gross abnormalities of the internal organs were noted, and there were abundant deposits of renal fat. The stomach contained portions of cottontail rabbit.

The skeleton of the dwarf fox was cleaned and compared with other gray fox skeletons. Figure 2 shows the lateral view of the skull of a normal male gray fox and of the broad, short (brachycephalic) skull of the dwarf specimen. The mandible of the latter extends past the body of the premaxilla and the mandibular incisors, and the canine teeth jut up in front of the nose as in the bull dog. The cranium of the dwarf animal was more dome-shaped than were those of gray fox skulls compared with it. The teeth of the upper and lower jaws of the dwarf were crowded, and the premolars of the upper jaws were set at angles as in the cocker spaniel (Sisson and Grossman, 1958).

Figure 3 shows the dorsal view of the skulls of a normal male gray fox and the dwarf fox. In the latter, shortness of the skull and the larger proportion of lyrate area between the temporal ridges are apparent. A cephalic index [2] of 67 for the skull of the dwarf fox compared with a mean of 55 for the indices of the skulls of eight normal male gray foxes taken in New York State. The shortening of the dwarf fox's skull is reflected by the greater cephalic index.

The dwarf fox appeared to be a juvenile, since the proximal epiphysis of the humerus was still open. Length measurements of the humerus, radius, ulna, femur, tibia and fibula showed them to be about 75 per cent of those of the corresponding bones from two normal juvenile gray foxes. The dwarf specimen's bones, although shortened, did not appear otherwise abnormal.

Great variation occurs in the inherited skull and body characteristics of the domestic dog, as evidenced by the numerous breeds. This wide variation in body morphology normally is not seen in wild fox populations. Genetic changes are believed responsible for the dwarfism observed. Although the dwarf fox's body size and morphology were considerably altered, it had apparently fared well in the wild until injured.

LITERATURE CITED

Blair, W. F., A. P. Blair, P. Brodkorb, F. R. Cagle and G. A. Moore. 1957. Vertebrates of the United States. McGraw-Hill Book Company, Inc. New York.

Sisson, S., and J. D. Grossman. 1953. Anatomy of the Domestic Animals. W. B. Saunders Company. Philadelphia.

Wood, J. E. 1958. Age structure and productivity of a gray fox population. Jour. Mammal. 39(1):74–86.

[2] Cephalic index $= \frac{\text{zygomatic summit breadth} \times 100}{\text{length}}$ (Sisson and Grossman, 1958).

FLOY TAG RETENTION BY SMALL BROOK TROUT [1]

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Thorson (1967) and Dell (1968) described the Floy tag and its applicator as well as preliminary observations on the use of this apparatus for tagging rainbow trout (*Salmo gairdneri*). Thorson stated he did not study tag retention, but he reported that six trout, marked with Floy tags and alive 3 months after tagging, had retained their tags. Dell reported no significant (95 per cent) difference between the number of Floy tags and Petersen disc tags returned from trout, from 26 to 41 centimeters (10.24–16.14 inches) in total length when tagged, caught within 2 months after release. He stated that fishermen reported that Floy tags were firmly attached and that wounds were minimal. In his list of desirable applicator features, Dell noted that these tags can be applied uniformly and precisely even by inexperienced taggers.

The need for a tag to mark small brook trout (*Salvelinus fontinalis*) prompted a test of Floy tag retention by fall fingerling and spring yearling brook trout. The test was started in a privately owned 2.5-acre Adirondack bog pond. It included 75 domestic-strain brook trout, ranging from 3.9 to 6.5 inches in total length, that were tagged and stocked as fall fingerlings in 1968 and 81 lot mates from the same hatchery, ranging from 5.5 to 8.4 inches in total length, that were tagged and stocked as spring yearlings in 1969. Fish of both plantings were given distinctive fin clips and were tagged at the hatchery on the day prior to stocking. A model FDM-68 applicator was used to insert serially numbered model FD-67 #20 Floy tags [2] into the right side of unanesthetized brook trout that were held immobile in a frame-type device of aluminum and ¼-inch knotless nylon netting. The tags were placed approximately 60 per cent of the distance from the lateral line to the insertion of the dorsal fin, angled forward approximately 45°, directed upward toward the anterior edge of the dorsal fin and inserted to a depth where the junction of the vinyl tubing and nylon anchor stem was flush with the skin of the trout. Data were collected by trap netting and gill netting in the spring of 1969 and by reclamation with rotenone the following August.

Initial findings were discouraging. Of the recovered trout that had been stocked as fall fingerlings, 18 of 43 (42 per cent) retained their tags over winter and 3 of 30 (10 per cent) retained them to the time of reclamation in late August. Of their 45 recovered lot mates that had been stocked as spring yearlings, 14 (31 per cent) retained their tags to the time of reclamation. The tags appeared to work out of the fish slowly. Generally, a large portion of the anchor stem and, in some cases, one prong of the anchor protruded from the skin. Fish that were shedding tags or had lost their tags shortly before recovery were marked with ulcers at the sites of anchor stem and anchor prong penetration. Fish that had lost tags and healed before recovery bore dark, generally elongate, axially directed scars, approximately 0.50 to 0.75 inch long. Some scars were irregularly shaped. Floy tags that had been placed high on the backs of several fish held and were not accompanied by the ulceration generally encountered. Dissection of these fish disclosed the engagement of at least one anchor prong in the interneurals of each fish.

The test was continued in a 76-acre Adirondack pond in 1970. A total of 214 brook trout produced in the pond, ranging from 5.2 to 9.6 inches in total length and considered to be spring yearlings, were trap netted, Floy tagged and released. To assure tag engagement of the interneurals, these fish were tagged higher on the back than those tagged previously (Figure 1). Some were tagged on the left side. Data were collected during angler interviews, gill netting and reclamation with rotenone. Of 41 trout, tagged and released in late May and recovered at the time of reclamation in late July, 40 (98 per cent) retained their tags. Tagging wounds

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-22-R. Acknowledgements are due Mr. Harold Hurley for the use of his pond and personnel of the New York State Department of Environmental Conservation, specifically, Erwin Annis for providing and stocking the domestic-strain brook trout and Wallace Gay, Daniel Plosila and Bruce White for helping to mark fish and collect data.

[2] Applicator and tags were purchased from the Floy Tag Manufacturing Company, Seattle, Washington 98105.

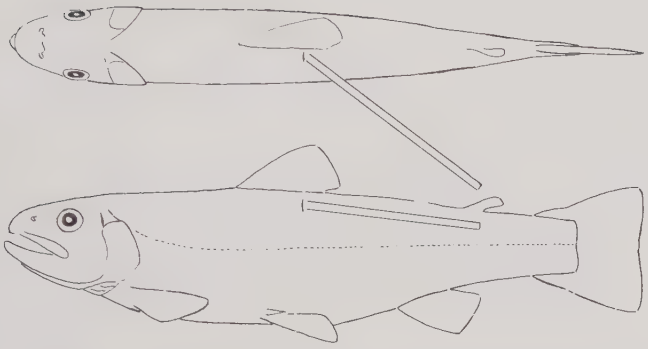

Figure 1. Diagram of dorso-lateral placement of Floy tag in a small brook trout.

were healing or healed on most of these fish. There was no apparent difference in tag retention between fish tagged on the left side and those tagged on the right side.

Satisfactory retention of Floy tags by small brook trout is apparently dependent on tag placement to assure engagement of the interneurals.

LITERATURE CITED

Dell, Michael B. 1968. A new fish tag and rapid, cartridge-fed applicator. Trans. Am. Fish. Soc. 97(1):57–59.

Thorson, Kenneth N. 1967. A new high-speed tagging device. Calif. Fish and Game 53(4):289–292.

A TELEPHONE ANSWERING SERVICE FOR REPORTING HUNTER-KILLED BEARS [1]

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A new procedure for reporting black bears taken during the open season in New York was initiated in 1970. Besides mailing in the usual report card, a successful hunter was requested to report by telephone to a prearranged toll-free number within 48 hours after taking a bear.

There were several reasons for this approach. First, in connection with an intensive investigation being undertaken concerning the characteristics of the bear population in the Catskill region, there was a need to contact hunters shortly after their bear was taken. Material (e.g., teeth, tissues) from the bear's carcass could then be obtained before it was disposed of and the hunter himself could be interviewed while information regarding his hunt was still easily recalled. Second, it was believed that early contact with hunters in the Adirondack and central and western regions would increase the annual sample of jaws received at the Wildlife Research Laboratory for aging by the tooth-sectioning technique described by Sauer et al. (1966). Third, the over-all reporting rate might be improved if hunters were provided with a relatively simple means of reporting. As the rate is increased, the accuracy of the calculated kill is also increased.

The answering service was located near the Laboratory at Delmar, so that reports could be picked up each, or at least every other, day. The operators were instructed on answering the calls and were given forms on which to record all reports of bears taken. The actual request to the hunter, including the number to be dialed, was printed on both the special early bear season permit and the regular big game license.

Hunters who reported taking a bear in the Catskill region were informed that a biologist would contact them shortly to arrange for an interview. Hunters who reported taking a bear in the Adirondack or central and western regions were mailed a franked envelope designed to contain the lower jaw, with instructions for its removal and method of return.

The system was initiated on October 1, 1970, the opening day of the special early bear season in the Adirondacks. By the end of the regular big game season on December 1 and an extended season in the Catskills lasting to December 16, and allowing several days for late reports to come in, 444 telephone reports had been received (Table 1).

Switchboard operators experienced no unusual problems when receiving reports. Crank calls, or calls not related to the taking of bears did not occur. Several hunters did pose questions that were passed on to appropriate personnel for handling. Many explained that the bear's lower jaw either was at a taxidermy shop or could not be returned for some other reason. The cooperation and acceptance of the system by hunters appeared to be excellent. One complication was that the number could not be dialed from outside New York State; a note on the license calling attention to this should minimize the problem.

Prompt contact with Catskill hunters enabled project personnel to arrange for a personal visit to nearly every hunter that phoned in, and this close follow-up resulted in five other bears being located that would not otherwise have been reported. In addition, two reproductive tracts of female bears were recovered for examination after the hunters gave precise directions as to the locations in the woods where the animals had been dressed out. Because of the very complete knowledge obtained, the final kill figure of 40 as determined by this method was used for the Catskill region in 1970, rather than a calculated figure.

For the Adirondack region, the forwarding of envelopes to hunters who reported by telephone resulted in a final collection of 190 jaws, and 33 additional specimens were obtained at checking stations. This was substantially more than had been collected in any previous year since efforts to obtain jaws were begun in 1964. In 1969, when the telephone procedure was not used, envelopes had been handed to hunters who had bears examined at checking stations and resulted in 81 returns. The total bear kill in this region in 1969 was only slightly lower than that in 1970.

Telephone reports from Adirondack hunters during the regular season totalled 346, of which 193 (55.8 per cent) were also reported by a mailed card. In addition,

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-89-R.

TABLE 1. REPORTS OF HUNTER-KILLED BEARS RECEIVED THROUGH TELEPHONE ANSWERING SERVICE IN 1970

Region	Special season	Regular season	Total
Adirondack	61	346	407
Catskill	..	35	35
Central and western	..	2	2
Total	61	383	444

55 reports were received by card that were not reported by telephone. Therefore, considering both sources, the total number of bears reported was 401.

In calculating the reporting percentage (i.e., that fraction of hunters who pass through a checking station or are checked by a conservation officer, and who later report their bear) for the Adirondacks, both types of report were used. Of 113 bears observed at checking stations, 74 were reported (33 by both telephone and card, 31 telephone only and 10 by card only) for a percentage of 65.5. Using this, the kill was calculated as 612. This percentage was considerably higher than that (52.5 per cent) for 1969 and above that for all but four of the last 16 years when records have been kept.

It would appear that nearly 40 per cent (153 of 401) of reporting Adirondack hunters considered that the telephone report alone was sufficient cooperation. Another 14 per cent (55 of 401) for reasons unknown did not use the telephone service, but instead sent in the report card only. An estimated 211 hunters (612 less 401) failed to report by either method. Thus, continuation of the dual system would seem to afford the best means of achieving the maximum number of reports of bears taken.

The costs involved in telephone reporting were as follows: toll-free service from October 1 to December 20 through the New York Telephone Company's "wide area telephone service," $702.66; 24-hour answering service for the same period, $69.50. For the 444 calls received, the cost was $1.74 per report. However, any number of calls may be received for the same price.

Additional costs to consider are expenses to return the calls of hunters and to contact them personally and check their animals. These costs will vary depending on salaries of personnel, travel distances and the number of contacts. In 1970, the total expenditure for each of 37 Catskill bears examined at residences or camps was estimated at $30.

Practically, the system is most appropriate for sample sizes of 1,000 or fewer. If several thousand records were contemplated, the time involved would become a problem. On the average, each telephone report took 3 minutes to record.

As a procedure for merely recording the harvest of game animals, use of the telephone reporting system would seldom, if ever, be warranted. But for wildlife managers concerned with quickly contacting successful hunters to obtain teeth or tissue samples, to forward questionnaires or to arrange for further interview, it merits consideration.

LITERATURE CITED

SAUER, PEGGY R., STUART FREE AND STEPHEN BROWNE. 1966. Age determination in black bears from canine tooth sections. N.Y. Fish and Game Jour. 13(2):125–139.

Errata

In the paper "Distribution of big game licensees in New York" by Steve Eabry (New York Fish and Game Jour. 17(2):88-94), part of the sample of Albany County hunters was inadvertently omitted from the computations. This caused minor changes in all residence zones. As these changes are small and do not alter the substance of the paper, a detailed erratum will not be published here. However, the following may be noted. On page 89 (line 3), the figure 44,498 should read 44,703. In Table 1, the figures for the Albany-Troy zone should read 10,137, 2.0 and 2.1 (they presently read 8,239, 1.6 and 2.1). In Table 3, the figures for the Albany-Troy zone should read 2.7, 37.4, 8.0 and 12.6 (they presently read 2.2, 46.0, 6.5 and 15.4). A complete list of all changes is on file and may be obtained from: The Librarian, Wildlife Research Laboratory, Delmar, N.Y. 12054.

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